

JPRS-JST-93-018

10 JUNE 1993



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# ***JPRS Report***

# **Science & Technology**

***Japan***

COMPREHENSIVE DEVELOPMENT OF  
NEW SUNSHINE PLAN

19980506 079

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## SCIENCE & TECHNOLOGY JAPAN

### COMPREHENSIVE DEVELOPMENT OF NEW SUNSHINE PLAN

93FE0371A Tokyo INDUSTRIAL TECHNOLOGY COUNCIL, MITI in Japanese Dec 92 pp 1-84

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## Comprehensive Development of New Sunshine Plan

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### [Text] Introduction

In July 1990, the New Energy Development Subcommittee of the Industrial Technology Council summarized items "Concerning the Future Existence of the Sunshine Project (Strategies for Technological Development of New Energy in the Global Environment Era)," and in June 1990, the Energy Efficiency Technology Development Subcommittee summarized items "Concerning Progress in the Future Development of Energy Efficient Technology." After this, with the background of the growing common international recognition that it is necessary to quickly work out all possible policies for global environmental problems, beginning with global warming, it became necessary for this country make the "Global Reclamation Project," which had been proposed earlier, even more concrete.

On the other hand, under these strict environmental constraints, there are even greater expectations for continued economic growth and, in order to deal with the growing energy requirements and load on the environment that accompanies this, for solutions through new breakthroughs in technology that have been impossible with existing technology.

With these conditions as a background, a joint planning committee under three subcommittees, the New Energy Development Subcommittee, the Energy Efficient Technology Development Subcommittee and the Global Environmental Technology Subcommittee, was established in the Industrial Technology Council in January of this year, and examinations of the future existence of technological development that cut across the energy and environmental fields have been piling up. On the other hand, with lessons learned from the fact that these problems have an intimate relationship with economic growth and energy, wide-ranging comprehensive deliberations were even carried out starting in June of this year in the Special Joint Committee on Energy Environments from the Industrial Structure Council, the Advisory Committee for Energy and the Industrial Technology Council, and in November of this year, suggestions concerning the "Future Existence of Energy and Environmental Policies" were given,

Based on the examinations from the comprehensive viewpoint of the joint committee, the committee for this project has brought together an interim summary concerning the future overall existence of technological development in the energy and environmental fields.

However, the objects of the examinations are the foundational and basic technical fields revolving around the research carried out by national research institutes and the New Energy and Industrial Development Organization (NEDO). Since, among energy technologies, there are separate places for examination of the nuclear field by experts, and even though the field of individual requirements for general home electronic equipment and energy efficient technology for individual industries are important fields, they are at the point in which many people are working on them independently, so they were left out of the objects of the examinations. On the other hand, in terms of environmental technology, for wide-ranging technological systems for dealing with broad problems which include things like species preservation and sea contamination and for countermeasures for global warming and acid rain, examinations were carried out centered on fields intimately related to the use of energy revolving around the national research institutes' foundational and basic research related for the most part to global environmental technology and new technical developments by the Research Institute of Innovative Technology of the Earth.

Based on the above examinations, this interim summary is a summary of:

1. Along with showing the basics of energy and technological development that make possible continuous development,
2. The means for making progress on comprehensive development of energy and environmental technology, that is on the "New Sunshine Project," which is related to research and development in global environmental and industrial technology, based on this, and
3. Outlines of the important projects for this research and development.

In terms of the policies that must be enacted in order to solve global environmental problems, multifaceted examinations of economic policies such as those for transitions in industrial structure, environmental policies, energy policies and technological transitions are indispensable, and even in terms of the existence of technological development in the energy and environmental fields, positioning within this wide context is necessary. We expect that this interim summary will be the opportunity for touching off examinations that delve into specialized fields in each area associated with energy and the environment and that it will contribute to multifaceted examinations that can be thought of as developing in the future.

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## I. Fundamentals of Energy and Environmental Technology Development for Sustainable Development

### 1. Most Recent Circumstances Surrounding Development of Energy and Environmental Technology

#### (1) Actuality of Global Environmental Problems

Along with the growth in large-scale human economic and societal activities, the environmental load that accompanies these has increased and accumulated, and global environmental problems, starting with global warming, have become an actuality. Because of this, there has been an increase in the recognition of the fact that "the environment," in addition to the "energy and resources" that have been pointed out conventionally, is an important constraining factor for the long-term continuation of mankind as a whole, not just one country. In terms of their scale, effects and temporal spread, these environmental problems differ in nature from the local environmental problems up to now, and these are something that human beings must use their knowledge collectively to solve.

Accordingly, in order for all of the countries of the world to come together and carry out investigations for working on solutions to global environmental problems, the United Nations Conference on Environmental Development (UNCED, World Environmental Summit) was held in June of this year in Brazil, and under the concept of "sustainable development," there was mutual international agreement on the direction of working toward both the environment and development.

In the past, from an international standpoint, this country has proposed a "Global Reclamation Project," centered on technological developments and transitions, as a comprehensive response to global environmental problems, but in order to attain this concept, it is important to build up concrete programs from now on.

#### (2) New Views on Energy and Environmental Problems

With the actuality of global environmental problems as a background, a new point of view has been added to the international supply and demand for energy. In other words, the increase in energy usage, not by advanced countries alone, but on a world-wide scale that also includes developing countries, has become an urgent problem. In particular, if we take a lesson from the size of the wide-ranging effects on the global environment and effects on the energy supply worldwide of the resources and production of the developing countries, NIS and Eastern Europe, the necessity for working on making the utilization of energy in these countries more efficient and reducing the load on the environment is a problem for the entire world.

In addition, in terms of the supply of energy, a transition to cleaner energy sources that produce less CO<sub>2</sub>, which is the major factor in global warming, and other oxide pollutants is indispensable. From this point of view, the importance of energy sources that do not produce air pollutants, such as

nuclear energy and renewable energy, in the energy transition process is growing on the one hand, while on the other large constraints have been imposed on the use of fossil fuels, starting with coal. However, reserves of coal are abundant, and while most of the world's supply of energy depends on fossil fuels at present, there is no avoiding dependence on fossil fuels, which are a stable energy source, for continued development, starting with the coal producing developing nations. Therefore, in terms of the environmental constraints on energy supply, the establishment of production processes that make for efficient use of fossil fuels, starting with coal, with a reduced environmental load and fixation and efficient, ecological utilization of CO<sub>2</sub> are important problems, along with making transitions to energy sources with lower environmental loads.

### **(3) Our Position in International Society**

As a country that represents 15% of the world, we should actively contribute to the continuous development of international society with the constraints from the above aspects of energy and resources and from the environmental aspect. Actually, at the "Global Environment Convocation" held in Tokyo in April of this year and at the June "Global Environmental Summit," there were great expectations for the role that we should play in the solution of global environmental problems.

Because of this, there is a requirement for us to examine multifaceted contributions that make use of our economic, political and technological potential. In particular, in order to solve global environmental problems, not only advanced countries, but also developing countries, hold the key, and in terms of this country, there is a necessity for us to carry out support through technological transition and technological cooperation with these countries, making use of our past experience in the energy and environmental fields.

In particular, the weakening of energy supply systems and the maintenance of safety in nuclear power generation in NIS and Eastern Europe have become large problems in the confusion that is accompanying the transition toward capitalist economies, and in Asia, including China, the necessity for response to energy requirements that will grow rapidly in the future and environmental policies that accompany growth in economic activities is becoming a reality; there is a need for support from us for the solution of these problems.

In these circumstances, concrete developments in technological development, technological transition and technological cooperation in the energy and environmental areas are an urgent necessity.

### **(4) Requirement for Construction of a Societal System that Harmonizes Economics, Energy and the Environment**

In this country, developments such as the aging society and labor shortage are predicted for the future, but in response to these circumstances, economic development, which is the foundation of a better, richer life, will continue, and construction of a society that is in harmony with the environment has

become a societal necessity. Even in the "Five Year Plan for Better Living Standards" that was decided upon in June of this year, there was a declaration of the necessity for the "construction of an economic society in harmony with the environment, and a country with a better standard of living that coexists with a global society that has realized production and consumption that is in harmony with the limited global environment."

In order to do this, it is necessary to aim at the construction of a society that makes optimal use of low environmental impact resources and energy that harmonize stable supplies of energy with environmental protection as the societal foundations that support economic development. In particular, in order to solve the "trinity" of problems of environmental protection, economic growth and stable supply and demand of energy, within the recent tendency toward increasing energy consumption, the securing of the attainment of "the goal of an energy supply that is an alternative to oil," which is behind the pressing goal of the "Global Warming Prevention Project" has become an important problem. In addition, concrete development of the "Global Reclamation Project," in both the long and short terms, has become an urgent necessity.

## 2. Basic Concepts of Energy and Environmental Technology Development

### (1) Basic Point of View on Energy and environmental technology development

Our generation is charged with building new capital on top of the capital of the previous generation. In other words, changing our point of view, we can say that the following generation has entrusted us with the Earth, and we are charged with passing it on in better shape rather than destroying it. Because of this, the problems of energy resources and the environment are constraining factors, and in order to solve these problems, political and societal solutions for the population problem, North-South problem and the problem of high energy consuming cultures and changing lifestyles centered on the advanced countries are also important, but in order for the human race to maintain continuous development while maintaining harmony with the global environment, we must aim at breakthroughs through technological development.

On the other hand, working toward this technological development will contribute to a stable domestic energy supply and efficient use of energy for this country itself, and it is indispensable for supporting an enriching lifestyle and economic development that are in harmony with the environment. In addition, it goes without saying that for this country, which ranks in the top level among large energy consumers, the promotion of our own energy efficiency and variety of energy sources will contribute to relieving the burden on worldwide energy and the environment.

Because of this, this country should use the potential accumulated in the energy and environmental fields up to now to the utmost, and along with working toward the forwarding of research and development in these fields, we should actively propose and participate in international cooperative research in order to combine the world's knowledge in a way that crosses national borders. Furthermore, we should make use of our technical strength and

experience and contribute to an increase in technical standards through cooperative research and technical change, especially for developing countries.

## **(2) Necessity for Comprehensive Promotion of Energy and Environmental Technology Development**

In terms of technological development in energy and environmental areas, research and development over the long term, based on connections between industry, government and universities has been energetically promoted in this country for 19 years with the "Sunshine Project" for new energy technology and 15 years with the "Moonlight Project" for energy efficient technology, and as a result, there has been an increase in the accumulation of technology and technological development potential with each project, and we have obtained steady results in research and development through national projects such as the establishment of basic technology, inducing related technological development in industry and making the results practical. In addition, in correspondence with the rising concern about global environmental problems in recent years and at the same time as reduction of global environmental impact started to come under close scrutiny, a research and development system for global environmental technology was started in 1989, centered on national research institutes. In addition, through cooperation among industry, universities and government, the Global Environmental and Industrial Technology Research Organization was established in 1990, and research and development projects for fixation and efficient use of carbon dioxide, etc., have gotten started.

In this way, each country, starting with this country, is going ahead with its own research and development concerning new energy technology, energy efficiency technology and global environmental technology, but since global environmental problems, starting with global warming, and energy problems are two sides of the same coin, there is a necessity for examining technical research and development policies for these from a comprehensive viewpoint, while constructing an ideology for a solution with a balance between energy constraints and environmental constraints.

At this time, there is a necessity for pushing forward, while carrying out comprehensive evaluations in which the viewpoint of environmental preservation is added for energy technology and the viewpoint of energy expense for the technology for environmental policies, and furthermore, even when viewed from the technological standpoint, there are fields that overlap with new energy technology, energy efficiency technology and environmental policy technology and ones that have commonality with them; in addition, since there are not a few fields that are expected to offer mutual compensation, it is important that comprehensive promotion with organic connections between energy and environmental technology development be carried out taking this point into account.

In terms of dealing with this, research and development will be carried out more rationally and rapidly with limited time, funds and personnel in the future, and it will be effective for developing large-scale energy and

environmental systems technologies for which grand results that cannot be obtained from independent research are expected.

### **(3) Characteristics and Limitations of Energy and Environmental Technology Development**

In terms of forwarding the development of energy and environmental technology, it is first important to have sufficient recognition of the characteristics and limitations.

#### **(i) First, because of the characteristics of "developing new technology,"**

a) there is a possibility of the generation of rapid results that increase the efficiency of economics and society overall, and while there are expectations for structural dreams for the future, there is a necessity for steady continuous research until a practical stage is reached, along with technical risks and uncertainty, and because of this, lead time is indispensable, and

b) while there is a possibility for constructing "international public funds" that can be used effectively by each of the world's countries for solution of energy and environmental problems which are problems common to the whole world, there is a hidden danger of "monopoly dealings."

#### **(ii) Second, because of "the first entrance of new products and production and utilization processes,"**

a) cost concepts that subsume their long-term, comprehensive value are not always established,

b) there are cases in which systems of laws and regulations and infrastructure for introduction and use are not complete, and

c) in addition, there is generally a low level of practice and maturity for usage, and normally there is a time lag between the establishment of technology and the above preparations.

(iii) Third, particularly in cases of energy technology to be introduced into this country, because there is already a highly developed system, and unless a situation in which the existing system is destroyed by a drastic rise in oil prices arises, there is a quantitative limit to substitutions for the current system, and there is a strong need for the significance of increasing the efficiency and leeway in the existing system and widening the variety.

Recognizing the above characteristics and limitations, the following should be our basic goals for the promotion of energy and environmental technology development matched with efforts toward the continued development of the existing system.

(i) While adding new possibilities to the existing system, we should increase the efficiency and leeway in the overall system and by broadening the variety and make the system strong.

(ii) We should continually lead with constructive dreams of possibilities for a better future, and irrespective of whether we are producers or consumers, we should bring together our vital forces, and continue our efforts without flagging.

(iii) We should accept the results of technological development and uniformly carry out preparations for societal and economic systems that accelerate their establishment.

(iv) The attitude of developing and sponsoring "international public funds" should be fundamental.

### 3. Future Existence of This Country's Energy and Environmental Technology Development

#### (1) Goals of Energy and Environmental Technology Development

We must establish the following policy items and through the devotion of our maximum efforts for achieving them, take the lead and work toward international cooperation for the furthering of this country's energy and environmental technology development.

(i) In order to make a response to the rise in energy and environmental constraints on a global scale, we must, under the ideology of the "Global Reclamation Project" and from both short and long-term points of view, (a) contribute to the actualization of industrial and societal systems that are harmonious with the environment and promote higher level utilization of energy and resources; (b) along with promoting the large-scale introduction of clean energy like renewable energy, (c) work toward making the utilization of fossil fuels, which have the highest level of maturity worldwide and the most developed infrastructure and for which there are abundant reserves, toward more efficient and higher levels and toward reducing their environmental impact; (d) and through challenges in development of new environmental technologies, help relieve worldwide energy constraints and reduce the impact on the environment.

(ii) In order to assure the "goal of alternatives to petroleum energy," which backs up the goals of the "Global Warming Prevention Project," which also keeps an eye on the recent tendency toward increased energy consumption, we must promote accelerated research and development related to technology that goes with the goal of realization.

(iii) Furthermore, we must promote technological breakthroughs with long-term international cooperation for global environmental problems such as acid rain, ozone layer destruction, waste, sea contamination, desertification and forest destruction, in addition to the problem of global warming.

## **(2) Priorities on Research and Development Topics for Energy and Environmental Technology**

In order to achieve the goals of the above policy items, we must first, using the following technology types, examine the direction that our country should follow in prioritization based on systematic evaluation and arrangement of the important technological problems that should be worked on worldwide from now on.

### **(i) Main technologies in this field**

- a) renewable energy utilization technology
- b) technology for making utilization of fossil fuels, beginning with coal, more efficient and higher level with less environmental impact
- c) technology for efficient transport and storage of energy
- d) technology for reducing the environmental impact generated by economic and societal activities from a worldwide standpoint
- e) new global environmental and industrial technology for the fixation and efficient utilization of CO<sub>2</sub>

(ii) Technology for construction of optimal combined systems with high efficiency and low environmental impact that can be expected to have rapid effects that cannot be obtained with individual technologies, through the optimal combination of main technologies

(iii) Basic and foundational technology that is conducive to the solution of problems common to the energy and environmental fields and seed research for the creation of new future technology

For this evaluation and arrangement:

(i) Based on the fact that, in order to solve energy and environmental problems, long, sustained work is necessary, (a) we expect that basic technologies will be established in the short and intermediate term (by the year 2000 or 2010), and (b) from the long-term point of view (after 2010), time phases for establishing technologies will be clarified, and

(ii) From the standpoint of promoting technological development that contributes to a relieving of energy and environmental constraints not only in correspondence with domestic policy needs, but also all across the international field, it is important that there be clarification of the direction of progress of research and development for (a) research and development topics that should mainly be worked on by advanced countries, starting with this country; (b) research and development topics that mainly contribute to solutions for the energy and environmental problems of developing countries; and (c) research and development topics that should be worked on a global scale through joint research by both advanced countries and developing countries.

If, based on the above, we evaluate and arrange the following 100 important research and development topics that are related to energy and environmental technologies, the new or continuous development and introduction of which should

be promoted on a worldwide scale starting with this country's industry, government and universities, we get what is shown in the appendix.

(i) Research and development topics (research and development that should aim for accelerated realization in the short and intermediate term, from the standpoints of possible volume of supply, possible amount of reduction in environmental impact, economy and reliability) that should have technology established in the short and intermediate term and should be worked on at an accelerated pace by advanced countries, starting with this one

(ii) Research and development topics (research and development for which the economic and reliability outlook should be clarified, along with promotion of technological breakthroughs for technologies that are potentially revolutionary and have large effects, even though the degree of maturity is less than those in (i)) that should be pushed forward to technological breakthroughs by advanced countries, starting with this one, from an intermediate- to long-term point of view

(iii) Research and development topics (technological research that is appropriate to the natural environment of the developing country, its society and economic environment which should help things take root) that should be actively worked on with the goal of reducing the energy and environmental constraints of developing countries from a short- and intermediate-term point of view

### **(3) Direction of Prioritization of Energy and Environmental Technology Development**

As was mentioned earlier, steady results for energy technology are coming from the research and development in the main technological fields in the Sunshine Project and Moonlight Project, and for global environmental technology, research and development projects in the Global Environmental Technology Research and Development System centered on national research institutes and the Global Environmental and Industrial Technology Research Organization are making progress; the directions of development are becoming clear. In order to play a leadership role in the attainment of the above mentioned "energy and environmental technology goals" based on the results of this research and the accumulated technology, the secret is evaluating the comparative geopolitical and technological priorities for this country along with the characteristics and limitations of each one, with the above mentioned evaluation and arrangement of important research and development topics as a base and based on the work being done overseas and a clear ordering of the expectations for environmentally friendly industrial and societal systems, and clarification of the direction of the energy and environmental technology research and development that should be given priority by this country. In this case, due consideration should be given to the importance of the development of systemization technology for constructing optimal combined systems through combinations of the main technologies along with the development of the main technologies themselves, widening our field of vision to international places from conventional domestic policies, moving forward actively on research cooperation that contributes to the raising of the capabilities for coping with the energy and environmental problems of developing countries along with promoting international joint research that contributes to

the relieving of energy and environmental constraints on a worldwide scale and strengthening technological foundations.

**(i) Directions of Important Research and Development for Each Field**

**a) Utilization technology for renewable energy**

These are sources of energy with a low environmental impact and inexhaustibility, but they are limited by natural and geographic conditions, and generally the energy density is low; by necessity they have the limitation of being centered on dispersed energy. Therefore, in this country we should actively go forward with research and development of them with the goal of developing supplemental energy that increases the efficiency, leeway and variety of the existing system, centered on "renewable energy that is technologically producible in quantity" and which has large possibilities for eliminating these constraints through technology.

In the short term, we should push forward the lowering of the cost and development of technology for practical high-volume production for the active introduction of solar heat into industrial fields and photovoltaic power generation, while establishing the basic technology. In addition, in terms of the technology for hydrogen production, there is the elemental technology that will be the key for development of the hydrogen based international clean energy system that was mentioned earlier, and it is important to accelerate research and development in earnest.

In the intermediate term, from the point of view of the possibility of exhibiting this country's comparative superiorities, there is a necessity for ascertaining the technological possibilities for deep geothermal power generation and binary cycle geothermal power generation. In terms of wind power, and ocean- and bioenergy, we should actively utilize the international cooperation of the IEA, etc., and cooperation with geopolitically advantageous developing countries and the fostering of the technological levels that can respond to these is important. In terms of bioenergy, we can also hope for progress from the standpoint of contributing to global environmental technology.

In the long term, there is a necessity for high efficiency solar cell technology and progress in hydrogen utilization technology.

**b) Technology for high level utilization of fossil fuels**

Setting our vision on technological developments for solving the problem of the struggle between the maintenance of a stable energy supply from a worldwide point of view and environmental protection, and particularly in the direction of the pursuit of full commonality and mutual compensation in other forms of energy and environmental technology, we should be clarifying important points and pushing forward with research and development.

In the short term, we should be pushing forward improvements in the efficiency and reliability of fuel cell power production, for which the basic technology is being established, and along with this technological development for practical use and lower cost.

In the intermediate term, there is a necessity for working on technological development that gives us a view of the possibilities for exhibition of comparative superiority in technological possibilities for power generation technology, combustion technology and fuel form conversion technology for more efficient utilization with less environmental impact of fossil fuels centered on coal, which has a high environmental impact but for which there are rich reserves, and in the supply of energy, but as an even more essential direction, it is, in the long term, important to aim at construction of environmentally friendly coal conversion complex technology, while promoting the fusion of hydrogen energy technologies, etc.

#### c) Energy transportation and storage technology

While being concerned about the tempo of development, we should carry out research and development on indicating important points, centered on higher efficiency, low loss and compact storage technology and long distance transport technology for electric power and heat, which are hard to store.

In the short term, we should place importance on working on technical developments related to high efficiency recovery of thermal energy, cascade utilization, transport and storage, which are the keys to the development of the wide energy network system mentioned earlier. In addition, we should actively push forward dispersed battery storage technology, particularly with the goal of applications in electric automobiles, aiming at establishing high-level technology that exhibits superiority over other technologies for reducing automobile exhaust.

In the intermediate and long term, we should promote the research and development for applications technology for superconducting power generation, which is expected to help improve power generation efficiency and increase transport quantities for single distribution line routes, taking into consideration development that allows for exhibition of its comparative superiority and the timing of introduction.

#### d) Technology for global environmental measures

In the short term, we should begin with technology for reducing the load on the environment, starting with development of alternatives for freon, and technology for reducing pollution caused by gasoline and diesel automobiles, and in the long term with CO<sub>2</sub> fixation, utilization and large-scale processing (storage) technology for the reduction of the overall amount of CO<sub>2</sub> produced, taking into consideration the fact that along with the development of environmentally friendly production technology like bioreactors, the use of fossil fuels, starting with coal, is indispensable from the energy standpoint.

In terms of the technology for global environmental measures, we are, at present, at the stage of groping with generally determined technology, so, considering the fact that the role of basic and foundational research and development is large in this field, promotion of the important points in this research is especially important, even more so than for energy technology.

#### (ii) Development of Systemization Technology

Along with the fact that the appropriate combining of several technologies makes it possible to surpass the limitations of single technologies and have higher level utilization of energy with a reduction of the load on the environment, it makes possible the extraction of strong points to the utmost, while compensating for the shortcomings of the individual technologies. In the future, we can assume that the importance of research and development concerning these combined systems will grow even more.

In particular, we should take a leadership role on a worldwide scale through joint research in promoting the World Energy Network (WE-NET), which will help in the establishment of a hydrogen utilization system for making a contribution to solving global environmental problems and relieving international energy supply and demand problems through the promotion of the introduction of clean energy on a global scale, converting clean, renewable energy, the abundant supply of which is still unused worldwide, into transportable forms such as hydrogen and transporting it to places of demand all over the world.

In addition, we should promote research on a Wide Energy Network System (Eco-Energy City Concept) that aims at construction of systems for optimal utilization of energy corresponding to the characteristics of city areas, local nuclear cities and industrial areas in order to improve energy utilization efficiency and reduce environmental impact for the society as a whole, through the optimal combination of high efficiency low temperature heat recovery, cascade utilization, revolutionary high efficiency transport and storage technology, etc., in thermal fields.

Furthermore, research on an economical and environmental friendly coal conversion complex that will make a great reduction in the costs of the

liquefaction process and CO<sub>2</sub> output through a combination coal utilization technology centered on coal liquefaction technology and hydrogen from WE-NET is important.

#### (iii) Basic and Foundational Research

It is indispensable to work on the development of energy and environmental technology from a long-term standpoint, and it is important to work on technical development, for example, broad-based basic and foundational research for the technical development of new processes to bring about a revolutionary reduction in the units of energy and the impact on the environment, that makes possible a rapid impact if the technical problems are clear, while giving expectations of practical use in the short term and to aid in the diversification of technical options for the future.

In addition, we must promote comprehensive, steady research and development for basic and foundational research concerning revolutionary materials, media, combustion and measurements, which make breakthroughs in individual elemental technical research possible and are technologies that are common to and form the foundation of research in the energy and environmental fields.

#### **(iv) Substantial Scientific Knowledge**

Furthermore, foundational and software research, such as basic research for observation and measurement, support for energy and environmental technical development, databases for carrying out evaluation, research on technology evaluation and social science research concerning the societal costs and societal compatibility of appropriate technologies, is necessary, and continual, steady progress should be made.

#### **(4) System for Promoting Research and Development**

##### **(i) Role of the Government and the People**

Basically energy and environmental technology development (a) is something that works on problems that are common to mankind with the goal of constructing "international public funds"; (b) something that is difficult to bring into the normal market mechanism and for which it is generally difficult to expect leadership in timely technological development from private businesses; and (c) since the policy needs are comparatively clear and since there is a need for finding concurrence about these, combining this with related policies and tying it to practical use as rapidly as possible, the government has a large responsibility for foundational research right from the beginning and on the level of applications research and development. In addition, its role in the introduction of solar cells into public facilities, starting the "Wide Energy Network System" and other public groups is large.

It goes without saying that from the beginning, along with promoting the above research and development, promotion of applications research in which the private sector takes the main role is important for technology that is at or near the stage of application, while building policies for a smooth transfer of these results to them, suitability, tax policies and financing.

##### **(ii) Role of national research institutes and Universities**

The roles of the accumulation of scientific knowledge, creation and evaluation of technical seeds, basic and foundational research and the evaluation of research and development, starting with global environmental technology and on other development projects, in energy and environmental technology are very large, and the role played by national research institutes and universities is extremely important; in order to activate the research functions of these from now on, it is indispensable to emphasize support from financial and systematic aspects, starting with the Grand System, along with expansion of the coordinated system of national research institutes and universities for crossover areas in energy and the environment.

**(iii) How research and development should progress**

a. Examinations of systematic arrangements that push forward effective integrated research and development of related systems concerned with research and development of new energy technology, energy efficiency technology and global environmental technology should be carried out in order to promote comprehensive progress in energy and environmental technology development.

b. Based on internationally open progress for the carrying out of research and development:

(a) It is important that, while systematic feasibility studies for digging up new, advanced research topics and comparative evaluation of research being done are carried out, the results be connected with projects, while undergoing comprehensive evaluation.

(b) In addition, while making an intimate connection between energy and environmental policies in the selection of new projects, it is important to urge on the active concern of appropriate technology users.

(c) Furthermore, when it is necessary to maintain consistency with policies for other related fields in order to achieve policy goals at this time, it is important to emphasize policy connections that go beyond ministries within government divisions.

(d) Furthermore, on top of promoting consistent research and development, looking forward from basic research to applications research, making research results practical and popularization, it is important to emphasize a research evaluation system that appropriately reflects the point of view of appropriate technology users concerning interim evaluations several years ago.

**(iv) Maintenance of Research and Development Funds and Research Personnel**

If, following the previously mentioned goals, the comprehensive, planned progress of long term energy and environmental technology development is restricted more than other technical development by financial and personnel aspects, it will be a source for future trouble. Therefore, it is extremely important that we rapidly form mutual agreement among those concerned and promote planned maintenance of allowances for research and development funds and research personnel in correspondence with the significance of the research and development, according to the above ideas relating to the promotion of research and development for energy and environmental technology.

**4. Policies for Applications of Energy and Environmental Technology in This Country**

**(1) Importance of the Promotion of Introduction and Popularization of Energy and Environmental Technology**

In view of the importance of the energy problem and environmental problems, in particular, current conditions requiring as much effort as possible in terms of

countermeasures for global warming, it is important to promote the introduction and popularization of the results of research and development along with promotion of technological development and as a good a circulation of both as possible.

In particular, in terms of the introduction and popularization of new energy technology and energy efficiency technology, we in this country should, along with making as much effort as possible, serve as an example for other countries on our own initiative and be expected to work even more.

The promotion of quick practical applications of the results of this research and development contributes to the activation and acceleration of research and development through clarifying the direction of research and development, raising the morale of researchers and increasing investments in research and development. In addition, there are great expectations for a form of promotion of good circulation for increasing demand and lowering costs, starting with photovoltaic power generation and fuel cells. These kinds of results are also expected for environmental technology such as biodegradable plastics and bioreactors.

Therefore, it is important that policies for technological research and development in the energy and environmental fields be coupled with policies for introduction and popularization and that these move forward as the drive wheels of the same car.

## **(2) Promotion of Mass Production Technology and Verification Research Which Serve as Media for Applications**

The major barrier to the introduction and popularization of new energy and environmental technology is economics, but working toward a solution for this through technological development is the trigger for formation of good

circulation and because of this, it is important to aid the development of low cost mass production technology and improvements in economy and reliability and promote verification research that is tied to practical applications.

In addition, in terms of mass production systems for systems like those for photovoltaic power generation, the establishment of standard systems, lowering of costs through promotion of standardization research and the promotion of introduction by those with general requirements are important.

## **(3) Policies for Promotion of Introduction and Popularization**

Financial and systematic support policies are being constructed at present for new energy technologies and energy efficiency technologies for which the basic technology has been established and which are just about at the stage of practical application. However, even though there is an increase in expectations for these technologies as clean energy, conditions under which they can compete on economic terms with existing energy have not existed up to now, mainly due to market scale and lack of established distribution systems, and until the societal costs and hidden costs that are not reflected in market prices are included in some form or another, it is difficult at this point to respond to expectations

for introduction and popularization on a large scale. Therefore, while forming a societal consensus concerning costs and impact, based on comparisons of comprehensive results for energy and environmental factors, there is a need for promoting a broadening of policy for furthering introduction and popularization. Based on this sort of prerequisites, it is desirable to have sufficient examinations among those concerned with the policies for the promotion of introduction and popularization that are enumerated below.

**(i) Transfer of the Results of Government Research and Development to Private Concerns**

In order for private enterprises to proceed smoothly with practical applications using results obtained from government research and development, it is necessary that examinations of efficient policies for the handling of special permission for results and use of research and development capital be carried out.

**(ii) Financial Incentives**

In order to promote the introduction of costly equipment related to new energy and energy efficiency, one policy is the devising of financial incentives, but in order to promote the introduction of new energy technology and energy efficiency technology not only in industrial and business fields that already have a certain amount of incentives at present, but also in consumer fields, there is a need to examine the propriety of economic incentive grants through tax policies concerning the setting up of this related equipment.

In addition, there is a necessity for giving incentive grants through tax policies and capital financing for technological development related to environmental technology and establishment of production facilities for biodegradable plastics, etc., by private enterprises.

**(iii) Pilot Introduction in Public Facilities**

It is important to promote pioneering leading investments in new energy technology, energy efficiency technology and environmental countermeasure technology for public operations that will form the national infrastructure in the future. Therefore, we must actively promote advance introduction in public facilities for government and self-governing organizations and advance introduction in regional development projects.

**(iv) Systematic Environmental Preparation**

With the introduction of new technology, there is generally a the problem of having to clarify compatibility with various systems that have arisen premised on existing technology. However, with the introduction of new energy technology, there are already guidelines for connecting solar generation systems and wind power systems to the power system and plans for the purchasing of surplus power, and we must take a sufficient look at just how these will take root in actual usage, along with improvements in the economics of new energy technology, etc.

#### **(v) Connections between Ministries**

It is possible to devise more effective policies for the introduction of energy and environmental technology through intimate connections with policies from other fields; for example, for introduction into independent organizations, it is important to move forward with connections with the Ministry of Home Affairs and the cooperation of other related ministries. In particular, for completeness of scientific knowledge concerning global environmental problems, it is important to have exchange of information such as marine observations and ground observations, and the connections between the ministries concerned must be strengthened.

#### **(vi) Strengthening of Advertising and Information Supply Functions**

It is very difficult for users to get sufficient information about the technical content and economics of the introduction of new energy technology and energy efficiency technology, but it is important for the New Energy and Industrial Technology Development Organization (NEDO), which has accumulated research results as the central organization for carrying out research and development up to now, supply these research results and related information, perform consulting functions and accurately respond to the needs of those on the user side.

In addition, it is important to further global environmental; industrial technology with international understanding, and there is a need for substantial research exchange and information supply functions in the Research Institute of Innovative Technology of the Earth.

Furthermore, we must examine the strengthening of local information supply functions in order to promote the popularization of technology all over the country.

In addition, in order to increase the general awareness of citizens about new technology, there must be long term work in school education along with the promotion of popularization developments through awards, recognition and demonstrations.

#### **(4) Example of a Concrete Problem**

Out of all the new energy technologies and energy efficiency technologies, we will use photovoltaic power generation and fuel cells, for which the basic technology has been established and which are coming to the stage of practical application, as examples, and the following is a concrete example of the problems of introduction and popularization.

##### **(i) Photovoltaic Power Generation**

The greatest problem for photovoltaic power generation is the reduction of generation cost. An important key for doing this is the reduction of the cost of solar cells, which hold most of the cost for photovoltaic power generation systems. In order to reduce the cost of solar cells, it is important to improve capabilities such as conversion rate, develop technology that allows for the

realization of the level of capacity reached in the laboratory at the factory level, and furthermore, reduce costs through mass production based on the technology developed.

Reduction of the costs of peripheral equipment such as invertors and stands and furthermore, reduction in the costs of installation are also indispensable for reduction in the cost of systems overall, and in order to do this, it is important to bring about a reduction in costs through the mass production effects that accompany the creation of demand, along with promoting reductions in production costs through promotion of system unitization and simplification. In addition, increasing the convenience of general consumers through the preparation of sales routes for them and installation and maintenance by makers will contribute to the promotion of introduction and popularization.

#### (ii) Fuel Cells

The greatest problem for fuel cells is also the reduction of costs. As with photovoltaic power generation, it is important to reduce costs by means of the effects of mass production through creation of demand, along with reducing costs through improvements in performance through higher current density, and feedback from a large number of operational experiences, in order to do this.

In addition, construction of supply systems for propane and methanol, along with expansion of the natural gas supply network for fuel supply, and basic preparations for popularization are prerequisites for widespread introduction and popularization.

Furthermore, it is important to have the judgments of construction companies, which are the main organizations in construction, for the installation of fuel cells in buildings, and this is necessary for further expansion and establishment of the use of fuel cells; fuel cells must be developed in close coordination with those people in construction. In addition, it is necessary to promote field tests on the end user side, manufacturers, restaurants, hotels, etc., of fuel cell cogeneration, and it is important to supply information and carry out popularization development for these end users, including construction companies, all together.

In addition, it is important to promote active introduction in public operations that make use of the features of fuel cells, as in pioneering introduction in public facilities, like hospitals and area centers, that have large heat requirements and introduction in places like information and communications buildings that have much instrumentation that uses direct current.

### 5. Japan's International Role in Energy and Environmental Technology Development

#### (1) The State of International Research Cooperation

##### (i) Promotion of Joint International Research

Energy and environmental technology contributes to the solution of problems that are common to all mankind, and the promotion of research and development based

on international cooperation is indispensable. In this instance, it is important that we actively exhibit initiative in multi-country cooperation like that of the International Energy Agency and in two-country cooperation, based on the above mentioned arrangement of important research and development problems.

In particular, there is research and development on a global scale like that for WE-NET that can become worldwide international joint research projects that include not only the advanced countries, but also developing countries, and in terms of the advancement of projects, there is a necessity for examining systematic arrangements to make efficient research and development possible.

#### **(ii) Participation of Overseas Enterprises and Access to Results**

Along with thoroughly measuring the opportunities for participation by overseas enterprises at the beginning of national projects, there is a necessity for devising more efforts for easing the access of overseas enterprises to research and development results, through the holding of international symposia and creation and distribution reports of English abstracts. In particular, we should rapidly devise the same kind of handling as is used for measures already devised in global environmental and industrial projects for the results of energy technology development projects.

#### **(iii) International Communication of Research and Development Results**

We should widely communicate information concerning the results of research and development to the international community through presentations at professional societies, multinational information exchange through organizations like the IEA and information exchange in two-country frameworks.

In addition, in terms of the various information networks that the IEA and others are operating or examining, it is important that we make active contributions by supplying information from this country. Furthermore, we should examine the creation and opening of networks for the various databases at this country's research organizations and actively publicizing this country's research results and information in a form that is accessible from overseas.

#### **(iv) Substantial Scientific Knowledge**

In terms of global warming in particular, the accumulation of basic knowledge for the clarification of the global warming mechanism, which forms the foundation of research and development of technology for countermeasures, is just as important as that research and development, and starting with observations on a global scale, international cooperation is indispensable. It is important that this country bear part of the burden for development and use of observational and measurement equipment, accumulation of observational data, furthering of simulation research and accumulation of knowledge common to the whole world.

## **(2) Promotion of Energy and Environmental Technology Cooperation for Developing Countries**

It is impossible to solve international energy problems and global environmental problems without solving the energy and environmental problems in developing countries. However, if we consider the present economic positions and technological levels of developing countries, it is extremely difficult for them to solve these problems on their own. Therefore, it is important that this country actively push forward research and development cooperation and technology transfers for energy and environmental technology that is appropriate for the needs, natural environments and the societal and economic environments of developing countries and through this strengthen the growth of the people and the technological foundations of the developing countries and support improvements in their capabilities for dealing with energy and environmental problems. At this time, an approach in which joint research and development that establishes things for which the needs in the receiving country are high in terms of "appropriate technology" as objectives, rather than one-way cooperation or transfer, is important.

In particular, Asia and the Pacific rim should be considered important for this country, and using the framework of Asia-Pacific Economic Cooperation (APEC), and we should carry out comprehensive cooperative research in the energy and environmental fields that have taken hold in these areas.

In order to do this, we should organically combine the cooperative research, technical cooperation, dispatching of experts and receiving of trainees that have been being carried out independently in the above mentioned research fields for energy and environmental technology and carry out long-term comprehensive cooperation; for example, we should establish a research center that would become the nucleus of research and development in the energy and environmental fields within the Asia-Pacific region, and with this center as a base, examine the carrying out of improvements in research standards in the region and the promotion of stronger technological foundations through cooperative research, seminars, technical guidance and consulting.

Furthermore, not only should we have technological cooperation and cooperative research, but also, in order to improve the public welfare in developing countries, we should further the introduction of the active use of photovoltaic power generation, wind power generation, geothermal and other low environmental impact energy technologies and technology for environmental measures for capital grants in fields such as rural electrification, school electrification, medicine and agriculture.

In addition, in order to make a rapid response to the serious energy shortages and environmental pollution in NIS and the various countries of Eastern Europe, we should actively dispatch experts, receive researchers and carry out cooperative research like joint research in order to support a long-term strengthening of technological foundations, along with promoting technology transfer centered on technology for highly efficient utilization of coal and antipollution measures.

## Appendix

### 100 Important Research and Development Topics for Energy and Environmental Technology That Should Be Worked On Worldwide in the Future

(Framework) Research and development problems that should be worked on in an accelerated manner by Japan and the advanced countries for establishing technology

(Points of development) • Development of technology with consideration given to economic and reliable practical applications

<p>1. Renewable Energy</p>	<p>(1) Solar Energy</p> <ul style="list-style-type: none"> <li>•Low-cost, high efficiency solar cell production technology</li> <li>•Passive solar technology</li> </ul> <p>(2) Geothermal Energy</p> <ul style="list-style-type: none"> <li>•Deep geothermal power generation technology</li> <li>•Binary cycle power generation technology</li> </ul> <p>(3) Wind Energy</p> <ul style="list-style-type: none"> <li>•Collective wind power generation system technology</li> <li>•Large-scale wind power generation system technology</li> </ul> <p>(4) Hydrogen Energy</p> <ul style="list-style-type: none"> <li>•Fixed polymer hydrogen electrolytic process hydrogen production technology</li> </ul> <p>(5) Biomass Energy</p> <ul style="list-style-type: none"> <li>•Technology for conversion of waste resources into energy using biotechnology</li> </ul>
<p>2. High Level Utilization of Fossil Fuels</p> <ul style="list-style-type: none"> <li>•Raising the level of fossil fuel use</li> <li>•Higher energy efficiency</li> </ul>	<p>(1) Technology for Higher Energy Efficiency</p> <ul style="list-style-type: none"> <li>•Fuel cell power generation technology (verification for phosphoric acid type, molten carbonate type)</li> <li>•High temperature/high efficiency gas turbine power generation technology (ceramic gas turbine, etc.)</li> <li>•Coal gasification combined cycle power generation technology</li> <li>•Technology for hydrogen production using coal</li> <li>•Shape memory alloy engine technology</li> </ul> <p>(2) End Demand Energy Efficiency Technology</p> <ul style="list-style-type: none"> <li>•High efficiency insulation technology</li> </ul>

<p>3. Energy Transportation</p>	<p>(1) Energy Storage Technology</p> <ul style="list-style-type: none"> <li>•High efficiency thermal storage technology</li> <li>•Verification of new battery power storage technologies</li> </ul> <p>(2) Utilization Technology for Unused Energy</p> <ul style="list-style-type: none"> <li>•High efficiency heat pump technology</li> <li>•LNG cooling utilization technology</li> </ul> <p>(3) Energy Transport Technology</p> <ul style="list-style-type: none"> <li>•High efficiency thermal transport technology</li> </ul>
<p>4. Technology for environmental measures</p> <ul style="list-style-type: none"> <li>•Environmental measurement and effects evaluation</li> <li>•Global warming prevention measures</li> <li>•Acid rain prevention</li> <li>•Measures for preserving the ozone layer</li> <li>•Planting promotions</li> <li>•Sea and river contamination countermeasures</li> <li>•Technology for low environmental impact materials</li> <li>•Waste measures</li> </ul>	<p>(1) Acid Rain Countermeasure Technology</p> <ul style="list-style-type: none"> <li>•Diesel denitrification and desulfurization technology</li> <li>•lean burn combustion technology</li> <li>•low temperature combustion technology</li> <li>•catalytic combustion technology</li> </ul> <p>(2) Ozone Layer Protection Technology</p> <ul style="list-style-type: none"> <li>•Freon degradation technology</li> </ul> <p>(3) Sea and River Contamination Countermeasure Technology</p> <ul style="list-style-type: none"> <li>•Technology for decomposition of contaminants</li> </ul> <p>(4) Waste countermeasure technology</p> <ul style="list-style-type: none"> <li>•Metal recycling technology (iron, aluminum)</li> <li>•Recycling of compound plastics</li> </ul>

(27 topics)

(Framework) Research and development topics that should be pushed forward to technological breakthroughs in the long term by Japan and the advanced countries

- (Points of development)
- Breaking through technological bottlenecks
  - Clarity of economic and reliability outlook

<p>1. Renewable Energy</p>	<p>(1) Solar Energy</p> <ul style="list-style-type: none"> <li>•High efficiency solar cell technology</li> <li>•Bio-solar technology</li> </ul> <p>(2) Geothermal Energy</p> <ul style="list-style-type: none"> <li>•Hot rock geothermal power generation technology</li> </ul> <p>(3) Hydrogen Energy</p> <ul style="list-style-type: none"> <li>•Hydrogen burning turbine technology</li> </ul>
<p>2. High Level Utilization of Fossil Fuels</p> <ul style="list-style-type: none"> <li>•Raising the level of fossil fuel use</li> <li>•Higher energy efficiency</li> </ul>	<p>(1) Technology for Higher Energy Efficiency</p> <ul style="list-style-type: none"> <li>•Solid electrolyte fuel cell power generation technology</li> <li>•Superconducting power generator technology</li> <li>•Closed cycle MHD combined cycle power generation technology</li> <li>•Topping cycle pressurized entrained bed combustion power generation technology</li> </ul> <p>(2) Technology for Raising the Level of Utilization of Coal, etc.</p> <ul style="list-style-type: none"> <li>•Coal liquefaction technology</li> <li>•Higher level combustion technology</li> <li>•High level reformation technology for fossil fuels (synthetic gasses from methane, synthetic fuels production, coal [illegible] gasification technology, biochemical coal cleaning technology, etc.)</li> <li>•Partial cracking technology for coal</li> </ul>
<p>3. Energy Transportation</p>	<p>(1) Energy Storage Technology</p> <ul style="list-style-type: none"> <li>•Dispersed battery power storage technology</li> <li>•Superconductivity power storage technology</li> <li>•Seasonal thermal storage technology</li> </ul> <p>(2) Energy Transport Technology</p> <ul style="list-style-type: none"> <li>•High density thermal transport technology</li> <li>•Chemical thermal conversion technology</li> <li>•Superconductor transport technology</li> </ul>

<p>4. Technology for environmental measures</p> <ul style="list-style-type: none"> <li>•Environmental measurement and effects evaluation</li> <li>•Global warming prevention measures</li> <li>•Acid rain prevention</li> <li>•Measures for preserving the ozone layer</li> <li>•Planting promotions</li> <li>•Sea and river contamination countermeasures</li> <li>•Technology for low environmental impact materials</li> <li>•Waste measures</li> </ul>	<p>(1) Global Warming Prevention Technology</p> <ul style="list-style-type: none"> <li>•Physical absorption recovery technology</li> <li>•Chemical absorption recovery technology</li> <li>•High-temperature CO<sub>2</sub> separation technology</li> <li>•Efficient utilization technology for bacteria and CO<sub>2</sub> fixation for [illegible]</li> <li>•Efficient utilization technology for CO<sub>2</sub> fixation for hydrogenation</li> <li>•Artificial optical synthesis technology</li> <li>•CO<sub>2</sub>/O<sub>2</sub> burning boiler technology</li> <li>•Ocean and underground processing and storage technology</li> </ul> <p>(2) Acid Rain Countermeasure Technology</p> <ul style="list-style-type: none"> <li>•Low environmental impact car transportation system technology</li> <li>•High temperature exhaust processing technology (lime-gypsum, etc.)</li> <li>•Electron beam exhaust processing technology</li> <li>•Technology for desulfurization and ash removal using microorganisms</li> </ul> <p>(3) Ozone Layer Protection Technology</p> <ul style="list-style-type: none"> <li>•Third generation freon technology</li> </ul> <p>(4) Sea and River Contamination Countermeasure Technology</p> <ul style="list-style-type: none"> <li>•Technology for decomposition of contaminants</li> </ul> <p>(5) Waste countermeasure technology</p> <ul style="list-style-type: none"> <li>•biodegradable plastic technology</li> </ul>
<p>5. Systemization Technology</p>	<ul style="list-style-type: none"> <li>•High-efficiency cascade energy utilization</li> <li>•Wide energy utilization network system technology</li> <li>•Economic, environmentally friendly coal conversion complex technology</li> <li>•Eco-factory technology</li> <li>•Integrated energy system technology</li> <li>•Solar city technology</li> </ul>
<p>6. Basic and Foundational Technology</p>	<ul style="list-style-type: none"> <li>•Revolutionary energy materials technology</li> <li>•Revolutionary catalyst technology</li> <li>•Revolutionary bioreactor technology</li> </ul>

(42 topics)

(Framework) Research and development topics that should be actively worked on in the short term with the goal of easing constraints on developing countries

(Points of development) • Technological development for establishment through joint research appropriate to the circumstances in the developing country

<p>1. Renewable Energy</p>	<p>(1) Solar Energy</p> <ul style="list-style-type: none"> <li>•Photovoltaic power generation system technology (rural electrification, water pump systems, etc.)</li> <li>•Solar heat utilization systems technology (cooling, drying, cooking, etc.)</li> </ul> <p>(2) Geothermal Energy</p> <ul style="list-style-type: none"> <li>•Geothermal resource survey technology</li> </ul> <p>(3) Wind Energy</p> <ul style="list-style-type: none"> <li>•Wind conditions survey technology</li> <li>•Wind power generation system equipment and maintenance technology</li> </ul> <p>(4) Biomass Energy</p> <ul style="list-style-type: none"> <li>•Biomass combustion technology (gasification, liquefaction, etc.)</li> </ul> <p>(5) Sea energy</p> <ul style="list-style-type: none"> <li>•Oceanic temperature differential power generation technology</li> <li>•Wave power generation technology</li> </ul>
<p>2. High Level Utilization of Fossil Fuels</p> <ul style="list-style-type: none"> <li>•Raising the level of fossil fuel use</li> <li>•Higher energy efficiency</li> </ul>	<p>(1) Technology for Raising the Level of Utilization of Coal, etc.</p> <ul style="list-style-type: none"> <li>•Low grade coal utilization technology (liquefaction, gasification)</li> <li>•Coal ash removal technology</li> </ul> <p>(2) End Demand Energy Efficiency Technology</p> <ul style="list-style-type: none"> <li>•Technology for heat maintenance systems for boilers, etc.</li> </ul>
<p>3. Energy Transportation</p>	<p>(1) Utilization of Unused Energy</p> <ul style="list-style-type: none"> <li>•Utilization technology for heat pump waste heat</li> <li>•Simplified heat and cooling storage technology</li> </ul>

<p>4. Technology for environmental measures</p> <ul style="list-style-type: none"> <li>•Environmental measurement and effects evaluation</li> <li>•Global warming prevention measures</li> <li>•Acid rain prevention</li> <li>•Measures for preserving the ozone layer</li> <li>•Planting promotions</li> <li>•Sea and river contamination countermeasures</li> <li>•Technology for low environmental impact materials</li> <li>•Waste measures</li> </ul>	<p>(1) Global Warming Prevention Technology</p> <ul style="list-style-type: none"> <li>•Efficient biomass utilization technology</li> </ul> <p>(2) Acid Rain Countermeasure Technology</p> <ul style="list-style-type: none"> <li>•Technology for improving combustion air ratios</li> <li>•Simplified denitrification technology •Exhaust gas cleaning and processing technology</li> </ul> <p>(4) Sea and River Contamination Countermeasure Technology</p> <ul style="list-style-type: none"> <li>•Coagulating sedimentation technology</li> <li>•Activated sludge process technology</li> </ul> <p>(5) Waste countermeasure technology</p> <ul style="list-style-type: none"> <li>•collection measure technology</li> </ul>
<p>5. Systemization Technology</p>	<ul style="list-style-type: none"> <li>•Tree plantation system technology</li> </ul>

(21 topics)

(Framework) Research and development topics for furthering cooperative research in the long term worldwide

(Points of development) • Revolutionary technological development on a scale for which international joint research concentrates on the relative advantages of each country

1. Renewable Energy	<p>(1) Solar Energy</p> <ul style="list-style-type: none"> <li>•Systems technology for large-scale utilization of solar energy</li> <li>•Space solar development technology</li> </ul> <p>(2) Geothermal Energy</p> <ul style="list-style-type: none"> <li>•Magma development technology</li> </ul> <p>(3) Hydrogen Energy</p> <ul style="list-style-type: none"> <li>•New hydrogen technology</li> </ul>
2. High Level Utilization of Fossil Fuels	
<ul style="list-style-type: none"> <li>•Raising the level of fossil fuel use</li> <li>•Higher energy efficiency</li> </ul>	
3. Energy Transportation	
4. Technology for environmental measures	<p>(1) Environmental Measurement and Effects Evaluation Technology</p> <ul style="list-style-type: none"> <li>•Carbon circulation mechanism clarification</li> <li>•Construction of global observation system</li> </ul> <p>(2) Global Warming Prevention Technology</p> <ul style="list-style-type: none"> <li>•Technology for artificial creation of coral reefs</li> </ul> <p>(3) Planting Promotion Technology</p> <ul style="list-style-type: none"> <li>•Desert reclamation technology</li> </ul>
<ul style="list-style-type: none"> <li>•Environmental measurement and effects evaluation</li> <li>•Global warming prevention measures</li> <li>•Acid rain prevention</li> <li>•Measures for preserving the ozone layer</li> <li>•Planting promotions</li> <li>•Sea and river contamination countermeasures</li> <li>•Technology for low environmental impact materials</li> <li>•Waste measures</li> </ul>	
5. Systemization Technology	<ul style="list-style-type: none"> <li>•Technology for WE-NET</li> <li>•Coral reef reclamation system technology</li> </ul>

(10 topics)

## II. Comprehensive Development of Energy and Environmental Technology Developments

### 1. Construction of the New Sunshine Project

#### (1) Goals of the New Sunshine Project

(i) As was shown in section I, in order to strengthen the goals of this country's energy and environmental technology development, that is (a) relieving constraints on energy worldwide and lowering the environmental impact from a long-term standpoint based on the "Global Reclamation Project," and along with this (b) achieving "the goal of an alternative to petroleum energy," which backs up the goals of the "Global Warming Prevention Project," there is a necessity for organic, uniform coordination of research and development of new energy technology, energy efficiency technology and global environmental technology and promoting comprehensive technological development concerning the energy and environmental fields with these objects:

a. (a) utilization technology for renewable energy, (b) technology for efficient, high level, low environmental impact utilization of fossil fuels, starting with coal, (c) efficient energy transportation and storage technology and (d) individual revolutionary technologies for reduction of the environmental impact generated by economic and societal activities from a worldwide point of view;

b. technology for the construction of high efficiency, low environmental load, optimal combined systems that can be expected to have rapid effects that cannot be obtained through individual technologies, through the optimal combination of main technologies; and

c. seed research for the creation of new technology for the future and basic and foundational technology that will contribute to the solution of problems common to the energy and environmental fields.

(ii) Therefore, we have unified the Sunshine Project (new energy technology research and development: established 1974), the Moonlight Project (energy efficiency technology development: established 1978) and the Global Environmental Technology Research and Development System (established 1989) centered on technical research at national research institutes and established the "New Sunshine Project" (project for promotion of comprehensive research and development in the energy and environmental fields) which will perform a role in the "Global Reclamation Project" and make concrete revolutionary technological developments related to the "Global Warming Prevention Project"; it is necessary to begin revolutionary research and development aimed at the planned, comprehensive, simultaneous solution of problems with continual growth, energy and the environment.

(iii) Through the unification of the "New Sunshine Project," the commonality, mutual compensation and bidirectionality (the back and forth of environmental protection in energy technology and energy in environmental technology) of technologies related to new energy, energy efficiency and the global environment, which have been pushed forward independently up to now, will be exhibited for

unified problems for which "energy and the environment" are the flip sides, and we can expect effective and rapid progress in research and development for energy and environmental technology. (Reference 1)

(iv) In addition to the above, the "New Sunshine Project" has the significance of suggesting and illuminating through technology concrete conversion standards and their possibilities for the problem of "high energy consuming cultures and lifestyle conversions" which have thrown global environmental problems at mankind. In addition, through the internal and external indication of the necessity and possibilities for construction of new technological systems that form the axis of environmentally friendly energy technology, we can expect the effect of stimulating the formation of the necessary sense of values for continued economic and societal development. (Reference 2)

(Reference 1) Commonality, Mutual Compensation and Bidirectionality of Energy and Environmental Technology

	Item	New energy technology	Energy efficiency technology	Global environmental technology
Examples of Commonality	Heat exchange technology	Solar heat supply Geothermal (binary power generation) Coal liquefaction (slurry heat exchange technology)	Super heat pump (evaporator, condenser) Ceramic gas turbine (air preheating)	New heat pump refrigerant
	Advanced environmental materials	Deep geothermal/high temperature rock power generation (300°C +) Coal liquefaction (450°C, 170 atm) Coal based hydrogen production technology (1500~1800°C, 30 atm)	Ceramic gas turbine high temperature parts materials (135~0°C) Solid electrolyte fuel cell (about 1,000°C)	CO <sub>2</sub> high temperature separation, recovery and use (300°C)
	Energy storage technology	Hydrogen storage technology (hydrogen occlusion alloys) Photovoltaic storage device (hydrogen battery)	Super heat pump (chemical heat storage) Dispersed battery power storage (lithium battery)	CO <sub>2</sub> fixation technology using contact hydrogenation reactions (Utilization technology for heat absorption reactions)
Examples of Mutual Compensation	Economical, environmentally friendly coal conversion	Photovoltaic power generation ↓ <high efficiency electrolysis> Hydrogen production ----- CO <sub>2</sub> fixation/Utilization ↓ Coal liquefaction hydrogenolysis agent ↓ Economical environmental combustion system Coal liquefaction oil ----- (lean burn combustion denitrification catalyst)		
Examples of Bidirectionality		Evaluation of environmental effects accompanying geothermal development and coal liquefaction  (Energy development: global environmental protection viewpoint (Environmental technology: energy balance viewpoint	Development of alternate freon for super heat pumps	Evaluation of energy needed for CO <sub>2</sub> absorption and storage

(Reference 2) Examples of Cultural and Lifestyle Transition Models Suggested and Developed by the "New Sunshine Project"

#### **High Level Energy Utilization Cycle Model**

Promotion of thorough high level energy utilization cycle with recognition of the fact that the source of global environmental problems is unused thermal energy waste in energy consumption.

##### **Example: Wide Energy Utilization Network System (Eco-Energy Cities)**

Thermal energy from factories, etc., is efficiently recovered on a large scale, and through revolutionary technology for transporting it to cities and utilizing it, a high level cascade combined cycle utilization system is constructed for thermal energy; this will accelerate the high level cyclical utilization of thermal energy, the greater part of which is unused and wasted.

#### **Model of Working on Global Problems on a Global Scale**

Taking up the challenge of unification that exhibits mutual compensation of the geopolitical, economic and technological strengths of each country for dealing with global environmental problems that have spread out globally.

##### **Example: WE-NET**

Through the construction of an energy utilization network system with hydrogen as the medium from production through transportation and consumption, efficient utilization of clean energy on a global scale will be accelerated, while countries with resources and consumer countries carry out mutual cooperation.

#### **Model of an Energy Cultivation Culture**

Active introduction of energy utilization that brings together clean, renewable energy with a regeneration cycle to deal with global environmental problems that spread over time.

##### **Example: Revolutionary Technology for Renewable Energy Such as Solar and Wind Energy**

Active introduction of solar and wind renewable energy of and acceleration of the expansion of balanced energy utilization that holds down the increase in environmental impact.

(2) "New Sunshine Project" System

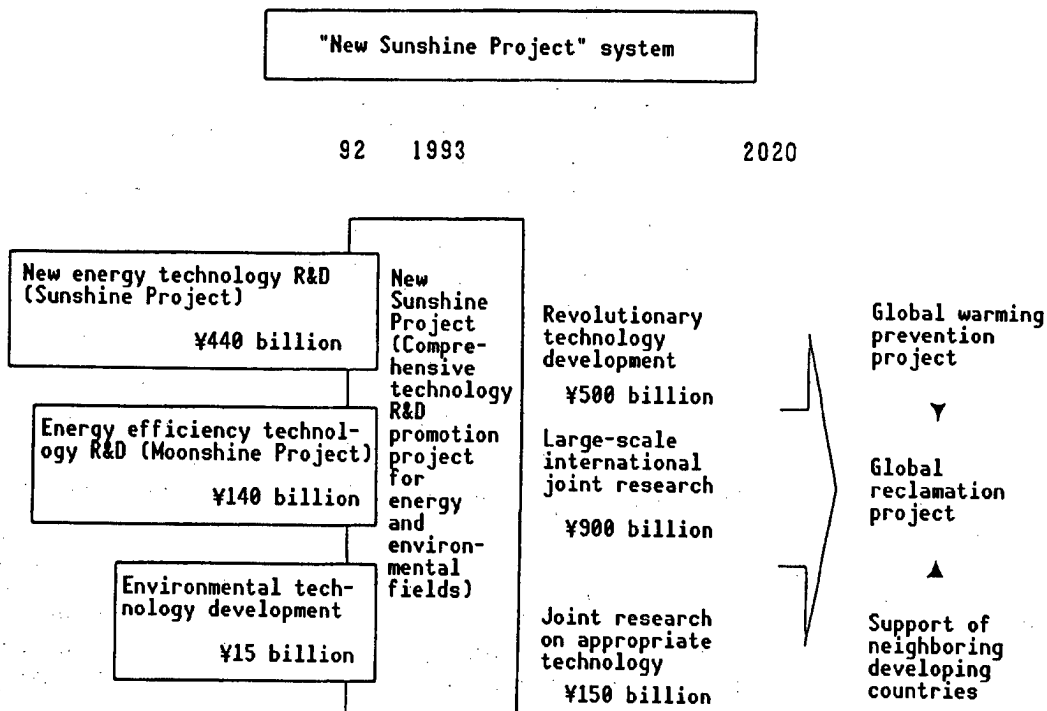
(i) The "New Sunshine Project" subsumes the following goals and is constructed of:

(a) accelerated promotion of revolutionary energy and environmental technology development projects that are slanted toward international openness and were actualization goals of the "Global Warming Prevention Project" ("revolutionary technology development")

(b) promotion of large-scale international joint research programs that were the goal of "World Reclamation Project" promotion ("large-scale international joint research") and

(c) promotion of programs for furthering joint research on appropriate technology for energy and the environment with the goal of relieving the energy and environmental constraints on neighboring developing countries (joint research on appropriate technology).

(ii) The research and development funds necessary for carrying out the "New Sunshine Project," along with "global environmental and industrial technology development," are expected to be a total of ¥1.55 trillion for the period of 1993~2020, and by this means, we can expect a contribution of the easing of one-third of this country's energy and one-half of its carbon dioxide output by the year 2030.



Note: See III. for details of estimates for funds necessary for R&D.

Contributions to the "Global Warming Prevention Project" and the  
"Global Reclamation Project"

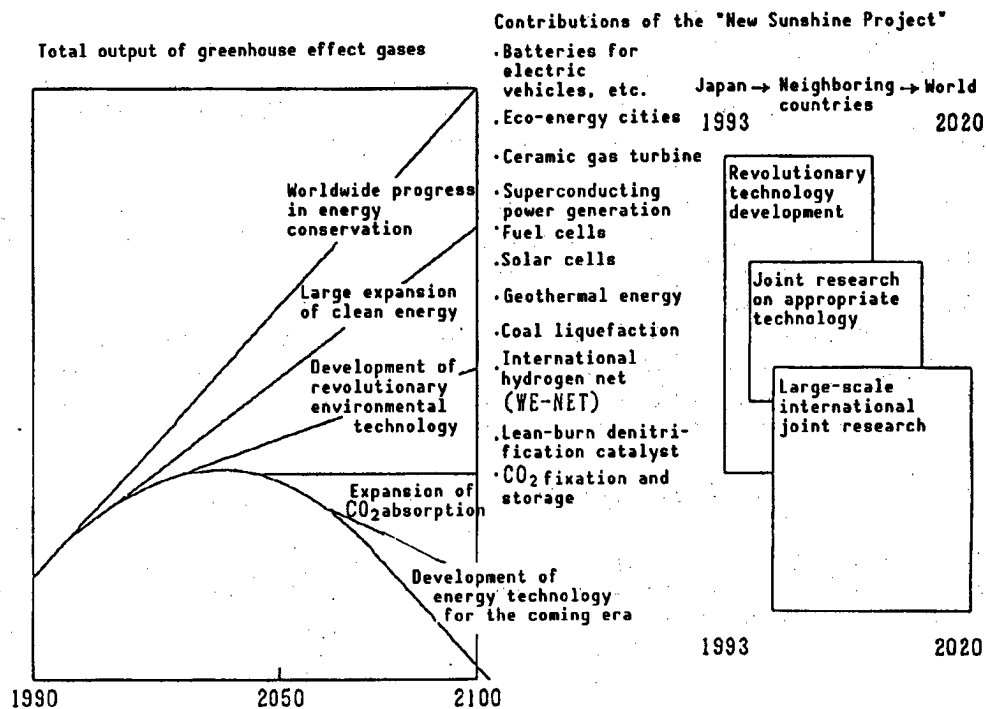


Image of Effects on Energy Supply and Demand  
and Carbon Dioxide Output

	Energy			CO <sub>2</sub> Reduction		
	Early 2000	2010-2020	Around 2030	Early 2000	2010-2020	Around 2030
Revolutionary technology	Several %	About 10%	About 24%	Several %	About 13%	About 30%
Large-scale joint international research	—	—	About 10%	—	About 3%	About 20%
Joint research on appropriate technology	—	—	—	—	—	—
Total	Several %	About 10%	About 34%	Several %	About 16%	About 50%

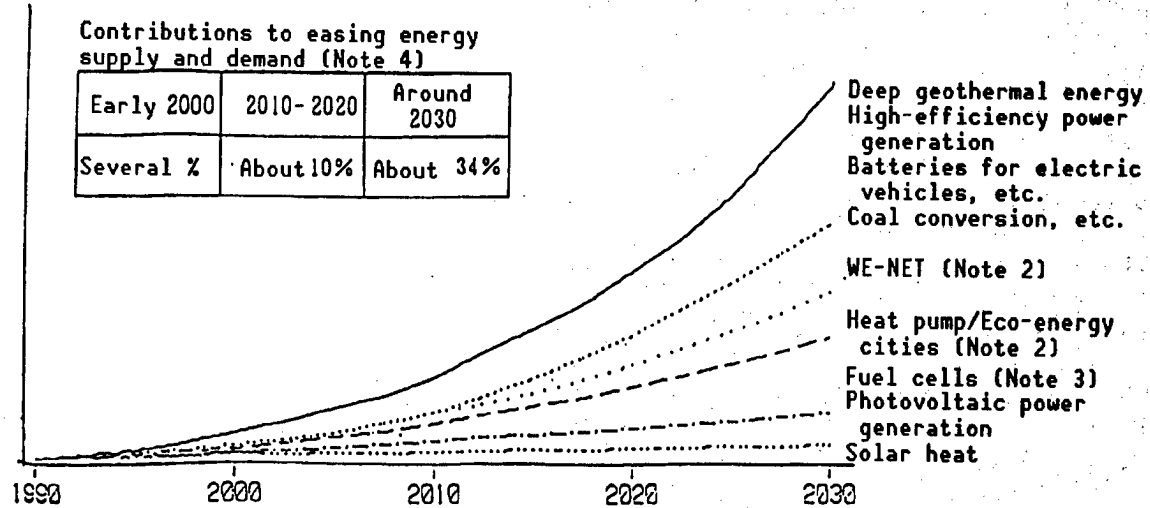
- Notes: 1. Energy: (amount of energy conserved+ new energy-total demand  
2. CO<sub>2</sub> reduction: (reduction in CO<sub>2</sub> output + CO<sub>2</sub> absorption x amount stored  
3. This gives an image of the potential of carrying out the "New Sunshine Project considering maximum efforts

Reference 3

Scenario of the Contribution of the "New Sunshine Project to Domestic Energy Supply and Demand and CO<sub>2</sub> Relief (Note 1)

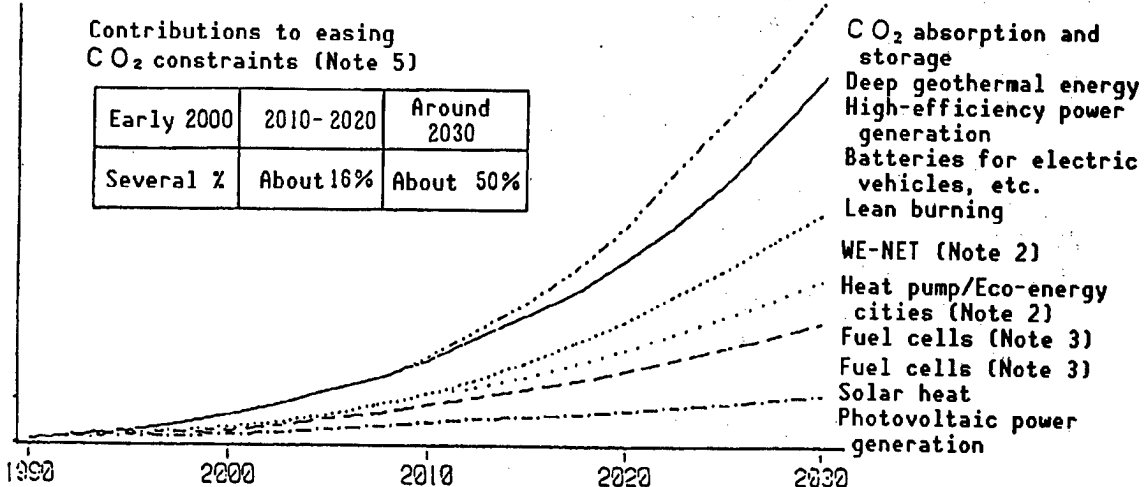
(1) Easing of energy supply and demand

Crude oil conversion



(2) CO<sub>2</sub> output inhibition and fixation

Carbon conversion



1. This gives an image of the potential for carrying out the "New Sunshine Project" in consideration of maximum efforts.
2. WE-NET: World Energy Network (utilizing overseas water power and solar power, etc.)
3. Total efficiency is raised through raising power generation efficiency and cogeneration
4. Contribution to Energy Relief: (energy conservation + total new energy contribution)/total energy supply (the total energy supply is the case in which the "New Sunshine Project" policies have been followed)
5. Contribution to CO<sub>2</sub> Constraint Relief: CO<sub>2</sub> output inhibition and reduction + absorption and storage/output (the total energy supply is the case in which the "New Sunshine Project" policies have been followed).

### (3) Basics of "New Sunshine Project" Development

(i) The cardinal point for the development of the "New Sunshine Project" is the exhibiting of the accumulated potential of the officials that have cultivated high-tech Japan, the Ministry of International Trade (MITI) and Industry and the Agency of Industrial Science and Technology (AIST).

(ii) On the other hand, the solutions to energy and environmental constraints are, as has been written, problems common to the whole world, and international efforts are indispensable; it is expected that the original experience in international joint research, beginning with Japan-Australia Brown Coal Liquefaction (1980-1990), IEA energy cooperation (1977- ) and cooperation of seven advanced countries on solar energy based on the Versailles Summit, accumulated at AIST will be exhibited to the full.

(iii) The basis for the development of the "New Sunshine Project," based on the experience and accumulated potential of these officials and with the goal of "constructing international public funds," should be

- a. promotion of high-level, effective research and development that combines the world's knowledge
- b. contribution of the research and development process and its results to the international community.

(iv) Concretely, our basic approach should be one in which,

- a. Along with accelerated promotion of research and development based on an internally and externally open system for "development of revolutionary technology," in which there are many elements we should take the initiative on focussed on the societal and geopolitical conditions of this country, such as "Wide Energy Network System technology (Eco-energy City)," we must make an effort to transfer the results;
- b. While working openly with the other countries involved to form areas for examination for "large-scale international joint research," in which there are a large number of elements to be worked on with mutual compensation of relative technological and geopolitical strengths by various countries, such as WE-NET,
  - (a) along with promoting the example setting breakthroughs in revolutionary elemental technology that this country should demonstrate,
  - (b) we should steadily [illegible] to construct an international joint research network.
- c. Technological and economic prospects for technologies like "appropriate technology for solar energy systems" and fuel cells are being established, and these have already been introduced in part; thus, we should undertake promotion of "joint research for appropriate technology" in technologies for which the appropriate technology needs in nearby developing countries are great, with the goal of establishing them in a way that is fitting to the natural, societal and economic environment in particular countries.

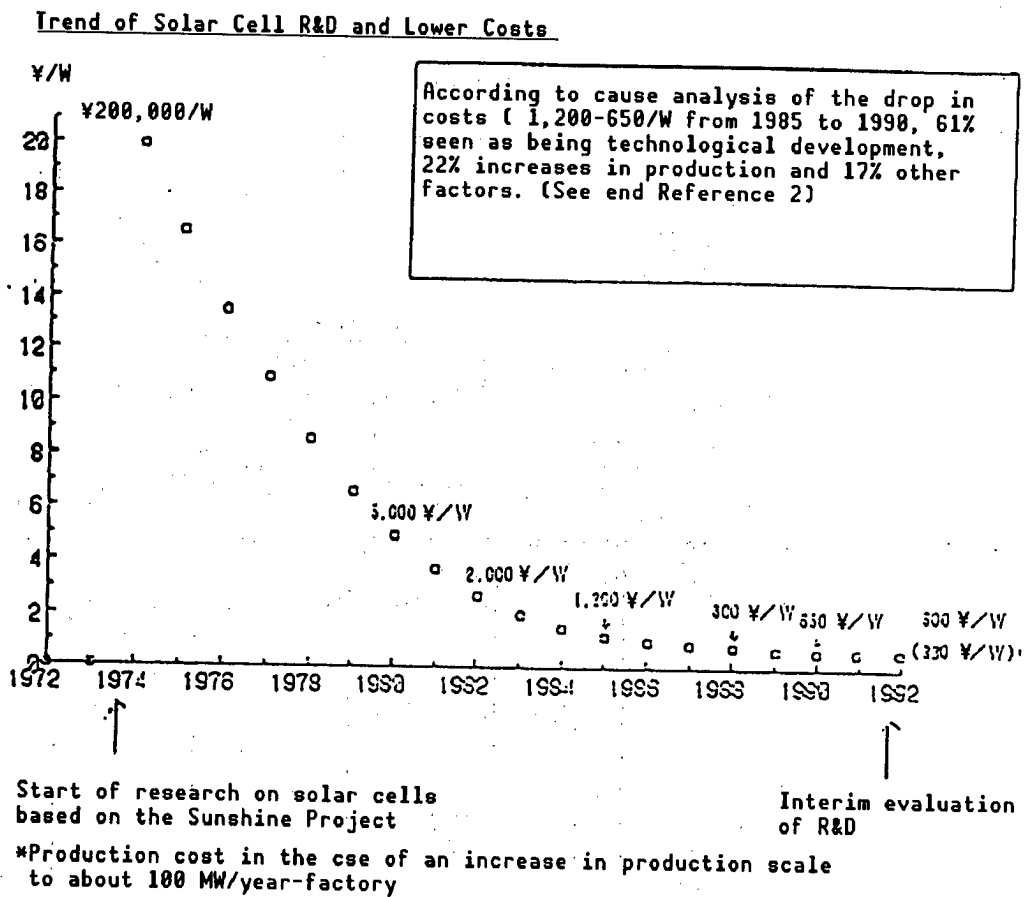
## 2. Work on Accelerated Development and Revolutionary Technology Development through the "New Sunshine Project"

### (1) Increasing Supply Potential through Accelerated Promotion of Technological Development

(i) Among the various new energy and energy efficiency technologies, research and development of solar cells and fuel cells has made rapid progress in recent years, and through this, we have reached a stage at which we have an outlook for a good cycle of reductions in cost due to technology and increases in demand.

(ii) However, there is a fixed lead time for the production facility capability and expansion of demand for real introduction of the results of these technologies.

(iii) Therefore, in order to strengthen attainment of "the goal of alternatives for the supply of oil energy" which is behind the goals of the "Global Warming Prevention Project," it is extremely important to carry out accelerated promotion of research and development of the above technologies and rapidly increase supply potential.



# Photovoltaic power generation

- ① Outlook for accelerated progress in R&D and lowering of costs
  - a) Accelerated promotion of R&D

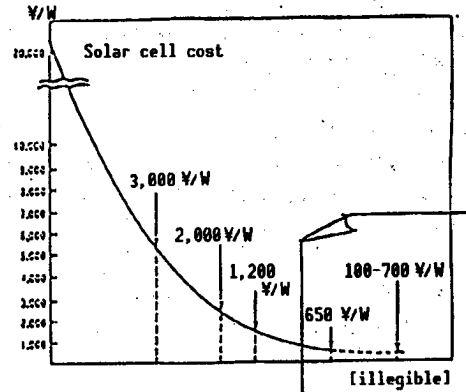
Increases in efficiency on the module level through optimization of structure and development of elemental technology of mass production

## (i) Multicrystal solar cells

- Increases in quality of solar cell substrates through electromagnetic casting, etc., and reductions in cost through increases in speed of substrate processing and simplification of processes
- Reduction in costs through achievement of module efficiency of 15% through optimization of module structure and use of a frameless structure and bunched distribution lines

## (ii) Amorphous solar cells

- Increase in [illegible] through use of film substrates and high-speed laser patterning, quality stabilization and development of technology to lower costs
- Establishment of technology to prevent optical deterioration, module efficiency of 10% after initial deterioration

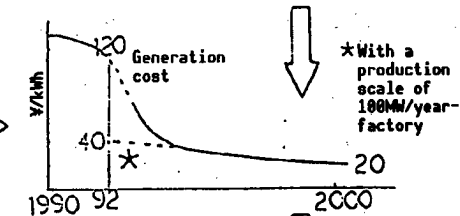
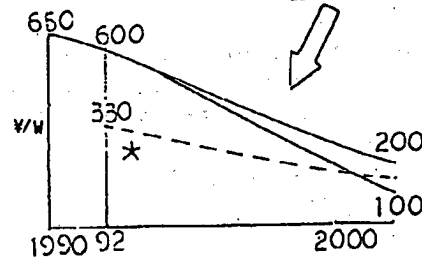


## b) Cost reduction outlook

	Technology at the end of 1992	Estimated technology by 2000
Total cost system	¥450/W approx.	¥220/W approx.
Solar cell	¥330/W approx.	¥150/W approx.
Peripheral equipment	¥120/W approx.	¥70/W approx.
Generation cost	¥40/kWh approx. <sup>1</sup>	¥20/kWh approx.
Pre-requisites	System utilization: Approx. 12% Production scale: 100 MW/yr-factory	

1. Production cost
2. Approximately ¥120/kWh at current production scale (20MW/year)

- ① Outlook for creation and expansion of demand and down costing
  - a) Outlook for initial stage of real use



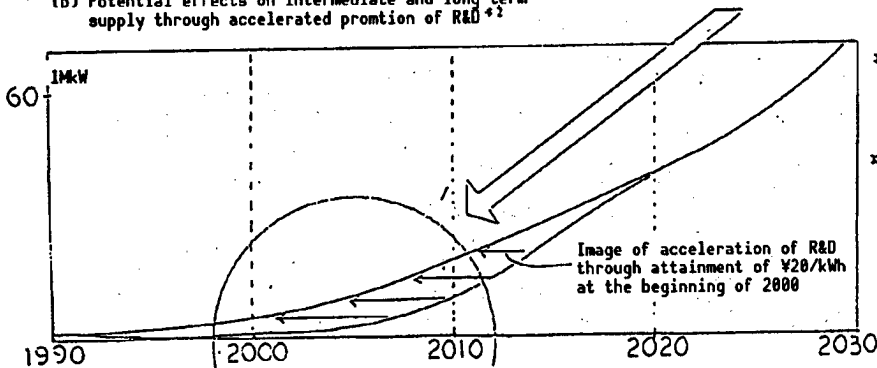
Good cycle of further down costing with increased demand

Accumulation

Image for outlook for application fields and demand scale according to cost<sup>2)</sup>

<sup>1)</sup> Amorphous Examination Subcommittee 1991 Report: Comprehensive Photovoltaic Power Generation Technology Research

- (b) Potential effects on intermediate and long-term supply through accelerated promotion of R&D<sup>3)</sup>



<sup>2)</sup> Shows an image of the establishment of supply potential through accelerated progress in R&D

<sup>3)</sup> 10M kW computed on a scale of normal power generation plants with 70% utilization

# Fuel Cell Development

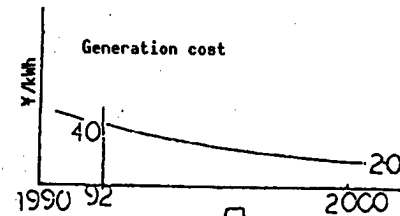
- ① Outlook for downcosting through accelerated promotion of R&D  
(a) Accelerated promotion of R&D

Higher Current Density for Cells and Verification Research Through Large-Scale Long-Term Operation

- (i) Reduction in cell cost
  - Higher current, greater output and larger surface area for cells
  - Greater lamination in cells
  - Higher performance catalyst
- (ii) Reducing size and cost of peripheral equipment
  - Combination and reduction in size of reformer and heat exchanger
  - Increasing of performance and life of reformer catalyst
- (iii) Large-scale long-term operations research
  - Verification operations research for confirmation of reliability, etc., necessary for practical use

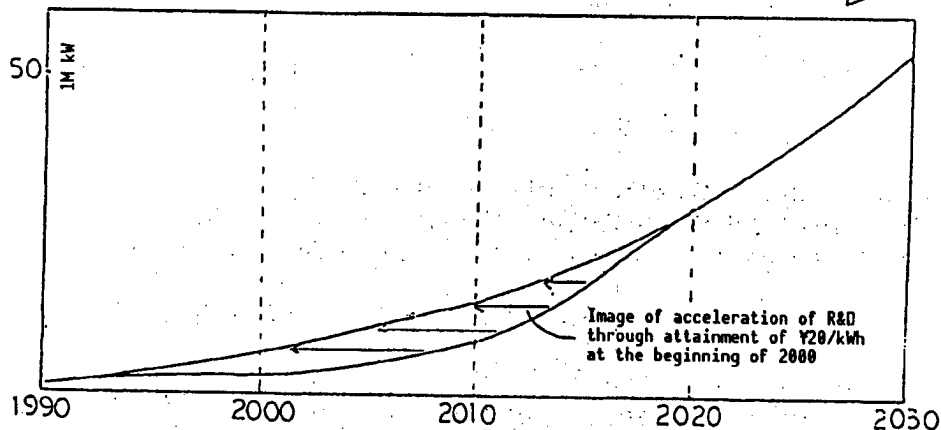
## b) Outlook for downcosting

	Technology at the end of 1992		
Total system cost	¥600/W approx.	→	¥300/W approx.
Fuel cell	¥240/W approx.	→	¥ 90/W approx.
Peripheral equipment	¥560/W approx.	→	¥210/W approx.
Generation cost	¥40/kWh approx.	→	¥20/kWh approx.
Pre-requisites	Facility utilization: 70% Fuel cell utilization: 40%		



Good cycle of further down costing with increased demand

- (ii) Image of potential effects on intermediate and long-term supply through accelerated promotion of R&D



## (2) Working toward Development of Revolutionary Technology

(i) In order to make steady progress on the "Global Reclamation Project," it is indispensable to not only make an effort at completing the "Global Warming Prevention Project" which has the 2010 as a final goal, but also work in parallel on the development of revolutionary technology that is expected to make a very large contribution to alleviating energy and environmental constraints in the long term.

(ii) Recognizing this, we are mustering the effects of "sunshine" and "moonlight" for the "New Sunshine Project," along with accelerated promotion of research and development on solar cells and fuel cells, and working on revolutionary technology like

- (a) Wide Energy Network System Technology (Eco-Energy City)
- (b) World Energy Network (WE-NET)
- (c) Economical, environmentally friendly combustion system technology that is expected to have very large effects in the long term.

Besides this, considering the fact that there is a great need for environmentally friendly uses (clean uses) for coal, the international demand for which can be seen as increasing drastically in the future, we want to establish and effectively promote "economical and ecological coal conversion complex technology" that musters the results of the above research and development of revolutionary technology for coal conversion technology that is already under progress, with the goal of making a central contribution to its realization.

(iii) The large contribution of the above to alleviating long-term energy and environmental constraints is expected to have the effect of stimulating the formation of the sense of values necessary for continual economic and societal development by externally and internally indicating the necessities and possibilities for constructing new technological systems that form the mainspring of environmentally friendly energy technology.

### Wide Energy Network System Technology (Eco-Energy City System)

Outline: High level thermal energy cascade and combined cycle system based on wide ranging high efficiency recovery of thermal energy from factories, etc.

Topics: (i) Elemental technology development for heat recovery and heating technology using the limits of sensible heat, thermal transportation and storage technology using chemical reactions and multifunction heat supply technology

(ii) Construction and optimization of a complete system that handles multiple, wide-ranging heat sources and demands

Effects: In cases in which utilization of the unused energy of the coastal areas near large cities is maximized, this will contribute 6% of the energy consumed in Japan and a reduction of 9% in CO<sub>2</sub> output.

#### WE-NET

Outline: Worldwide clean energy utilization system based on revolutionary technology from production to consumption, with hydrogen as the medium

Topics: (i) Elemental technology development for efficient, large-scale hydrogen production technology, high density hydrogen storage and transportation technology, hydrogen utilization technology such as hydrogen turbines, etc.

(ii) Construction and optimization of complete systems related to production, distribution and utilization on a global scale

Effects: Reduction of world CO<sub>2</sub> output by 10% at the popularization stage in 2030, and contribution of a 20% reduction by 2050

#### Economical and Ecological Combustion System Technology (Lean Burn Denitrification Catalyst Technology)

Outline: Exhaust gas denitrification catalyst technology for application in diesel and lean burn engines, with the goal of simultaneously improving vehicle fuel efficiency and reducing CO<sub>2</sub> and NO<sub>x</sub> emissions

Topics: (i) Elemental technology development for material and structural analysis of catalysts for high concentration oxygen atmospheres and new catalysts with improved thermal resistance, anticorrosiveness and life

(ii) Systemization of fuel, engine and exhaust systems for fuels that have good energy consumption and produce CO<sub>2</sub> and NO<sub>x</sub>

Effects: Contribution of 2% reduction in energy consumed, 2% of CO<sub>2</sub> emissions and 40% of NO<sub>x</sub> emissions in Japan, compared with conventional systems

#### Economical and Ecological Coal Conversion Complex Technology

Outline: Coal liquefaction system that makes for a great reduction in the cost of the liquefaction system and CO<sub>2</sub> emissions through a combination of a hydrogen utilization system that uses renewable energy and lean burn denitrification technology

Topics: (i) Establishment of core technology for coal liquefaction

(ii) Combining of the above technologies for hydrogen utilization and lean burning

Effects: Along with a 2% reduction in CO<sub>2</sub> emissions from coal liquefaction over conventional systems, a reduction in the cost of the product from \$35/B to \$25/B over conventional systems

### **(3) Promotion of Joint Research on Appropriate Technology**

(i) In order to get results from the "Global Reclamation Project," there is a necessity for transfer of technology to developing countries, along with breakthroughs in technological development.

(ii) In terms of technology transfer, it is important that what is established fits the natural, societal and economic environment and the technological level of the country receiving it, with the object being appropriate technologies for which the needs are great out of those which can contribute to relieving the energy and environmental constraints of the receiving country.

(iii) Recognizing this and while setting up technological and economic goals in the "New Sunshine Project," we hope to work toward "joint research on appropriate technology" that meets all of the goals in number (ii), with the objects being solar energy and fuel cell technology for which the needs in (ii) are very high, given technology that has already been introduced in part.

#### **Appropriate Technology for Systems Utilizing Solar Energy**

Outline: Application systems and improvement technology that fits the natural, societal and economic conditions and the research and development capabilities of developing countries from the solar energy utilization technology (already being introduced domestically) fostered by the Sunshine Project

Topics: (i) Improvements in durability under severe environmental conditions, and  
(ii) systems research for making maintenance free systems and reducing installation costs

Effects: Along with contributing to improvements in the energy and environmental problems (CO<sub>2</sub>, forest resources) in the countries concerned, "energy cultivation cultural standards" will be developed.

### **3. Promotion of Global Environmental and Industrial Technology Research and Development**

#### **(1) Basics of Global Environmental and Industrial Technology Research and Development**

(i) In order to deal with global environmental problems starting with global warming, it is important to develop the revolutionary environmental technology in the Global Reclamation Project for CO<sub>2</sub> fixation and utilization, and in addition to technological development in energy consumption and energy supply fields, dealing with them from a long-term point of view based on the CO<sub>2</sub> cycle mechanism is indispensable. In order to do this, there is a need for strong advances in research and development of "global environmental and industrial technologies," such as revolutionary environmental technology and development for CO<sub>2</sub> fixation and efficient utilization, environmentally friendly production

processes and low environmental impact materials and CO<sub>2</sub> absorption technology which are global environmental technologies for non-energy fields.

(ii) In order to do this, we will push forward research and development projects that are currently underway, starting with CO<sub>2</sub> fixation and efficient utilization technology, and along with working toward the realization of early introduction, and the promotion of research and development for not only the inhibition of CO<sub>2</sub> emissions, but also comprehensive CO<sub>2</sub> reduction technology, such as large volume storage for CO<sub>2</sub> and expansion of CO<sub>2</sub> absorption sources in the atmosphere, and revolutionary production process technology is necessary

(iii) Furthermore, from an even longer term point of view, along with the establishment of a system for uncovering and incubating research seeds which are in the foundational and germinal stages in a wide range of technological fields, there is an need for radically expanding international joint research and research support and promoting the Global Reclamation Project on a Worldwide scale.

## **(2) Development of Global Environmental and Industrial Technology Research and Development**

### **(i) Promotion of Research and Development Projects Currently Under Way**

#### **(a) Development of CO<sub>2</sub> fixation and efficient utilization technology**

- CO<sub>2</sub> fixation and efficient utilization technology for bacterial and pharmaceutical use (1990-1999)
- CO<sub>2</sub> fixation and efficient utilization technology for catalytic hydrogenation reactions (1990-1999)
- Technological development for high temperature separation of CO<sub>2</sub> and absorption utilization (1992-2001)

#### **(b) Technological development for lowering the impact of materials that have an environmental impact**

- Development of new refrigerant for compression heat pumps (1990-1994)
- R&D for biodegradable plastics (1990-1997)

#### **(c) Development of environmentally friendly production technologies**

- R&D for high level function chemosynthetic bioreactor (1990-1999)
- Technological development for environmentally friendly hydrogen production (1991-1998)
- Technological development for environmentally friendly substrates for metal system material recovery (1991-1998)

### **(ii) Carrying out new projects**

#### **(a) Fixation and storage of CO<sub>2</sub> using the oceans**

Carry out clarification of the global environmental carbon cycle mechanism placing importance on the oceans and basic research and evaluation of environmental effects concerning the introduction of CO<sub>2</sub> into the deep ocean and use of marine life such as algae and coral.

#### **(b) Development of environmentally friendly catalyst technology**

Develop new catalysts and living catalysts that have the characteristics of activity at normal temperatures and pressures and the necessary

selectivities in order to reduce the load of energy and materials on the environment.

**(c) Development of technology for fixation of carbon dioxide in desert areas through living organisms**

Carry out technical development on the cellular and genetic level in order to obtain plants that have CO<sub>2</sub> fixation functions even in the severe environment of desert areas that have high dormant potential for reducing CO<sub>2</sub>

**(iii) Perfection and Strengthening of the Research Institute of Innovative Technology of the Earth (RITE)**

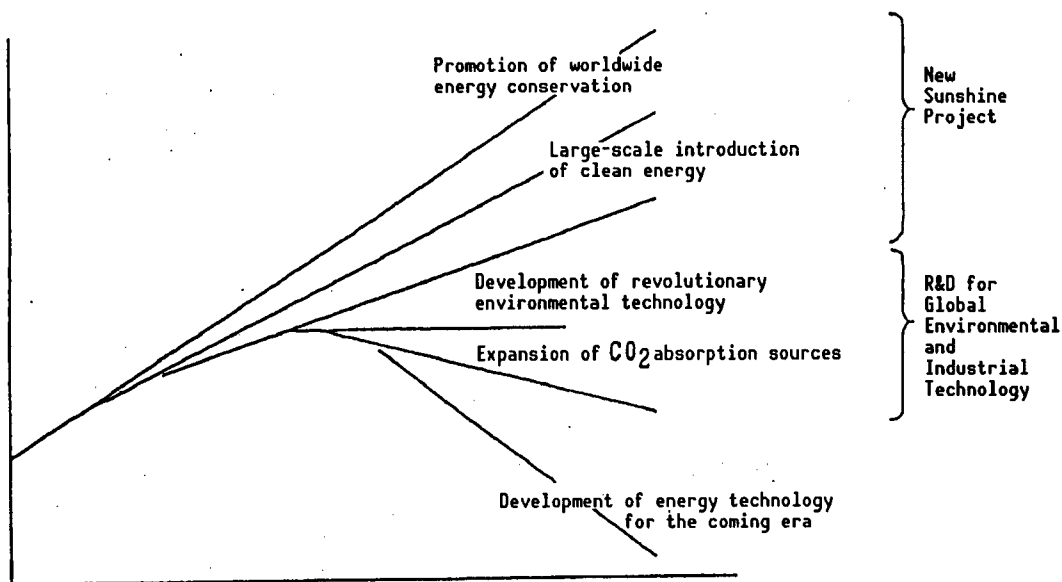
Position RITE, which will be completed in 1993, at the center of development for global environmental and industrial technology and strengthen its function as a base for carrying out basic research and important R&D projects and for international research exchange.

**(iv) Raising research seeds**

Advertise internationally for research project proposals in the foundational or germinal stage, and through support of research, effectively promote research on global environmental and industrial technology that musters scientific knowledge from a wide range.

**(v) International development of research and development**

Expand the international grant system, and along with promoting international joint research projects, expand exchange of researchers.



**Figure 1. Global Reclamation Project and R&D for Global Environmental and Industrial Technology**

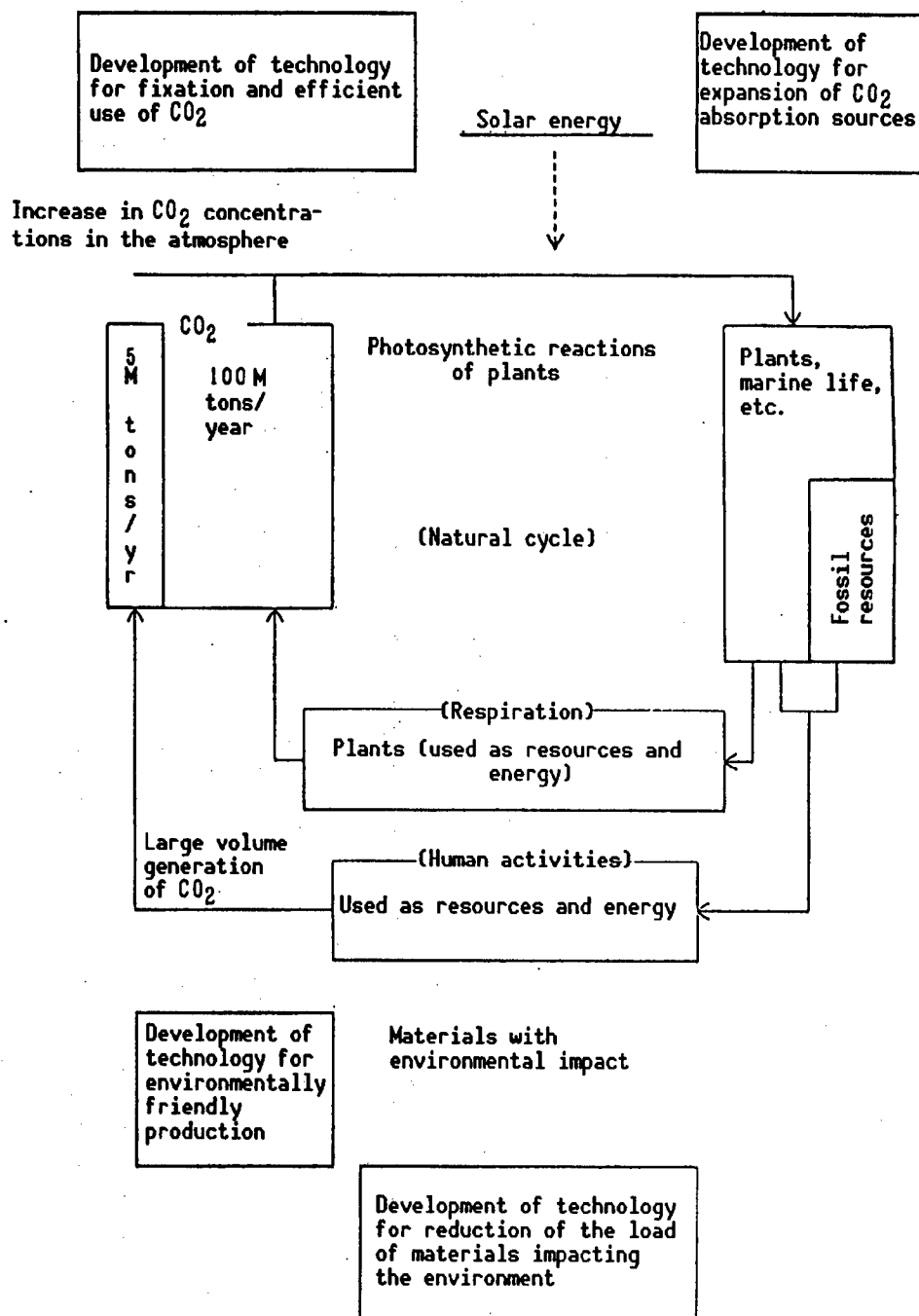
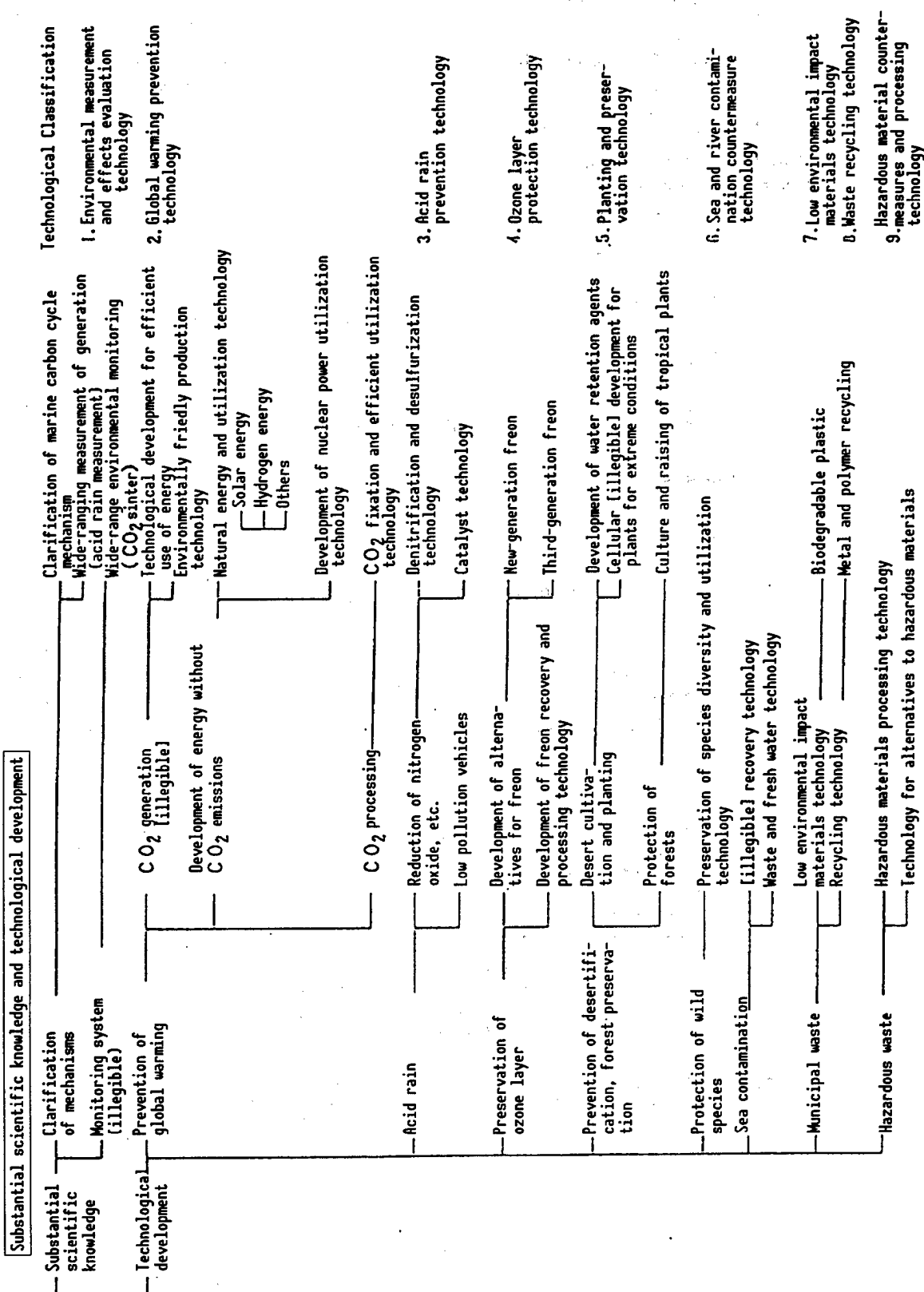


Figure 2. Main Targets of R&D for Global Environmental and Industrial Technology



**Characteristics and Technological Response for Global Environmental Problems**

	Cause/characteristics	Effects	Framework for countermeasures	Global technological response	
				Environmental technology (ex)	Effects of environmental technology
Global warming prevention	<ul style="list-style-type: none"> <li>•Nonhazardous materials cause</li> <li>•No current damage</li> <li>•Large number of unclarified parts and cause and effect relationships</li> <li>•Global effects</li> <li>•Currently technological response limited</li> <li>•Inescapably generated by human economic activities</li> </ul>	Rise in average temperature of 3°C and in sea level of 60cm by the end of 21 <sup>st</sup> Century	(International) climatic change framework conventions (Domestic) Global Warming Prevention Project	<ul style="list-style-type: none"> <li>•CO<sub>2</sub> recovery technology</li> <li>•CO<sub>2</sub> conversion technology</li> <li>•CO<sub>2</sub> emissions controlled production technology</li> <li>•CO<sub>2</sub> measurement technology</li> </ul>	Extensive control of CO <sub>2</sub> emissions from factories and power plants Clarification of global warming mechanism
Acid rain countermeasures	<ul style="list-style-type: none"> <li>•Damage such as forest destruction</li> <li>•International problem (multinational problem)</li> <li>•Technological response possible</li> </ul>	Bad effects on humans from air pollution in large cities Damage to lakes rivers and forests	(International/Europe) conventions on wide ranging air pollution crossing national borders (Domestic) air pollution prevention laws, NO <sub>x</sub> laws	<ul style="list-style-type: none"> <li>•Small-scale NO<sub>x</sub> catalyst technology</li> <li>•Low NO<sub>x</sub> burner technology</li> <li>•Small-scale SO<sub>x</sub> catalyst</li> </ul>	Control of NO <sub>x</sub> and SO <sub>x</sub> emissions from small and mobile sources
Ozone layer preservation	<ul style="list-style-type: none"> <li>•Promote chemical analysis and clarify why ozone layer destruction is greater than predicted</li> <li>•No direct damage at present</li> <li>•Global scale of increasing ultraviolet radiation</li> <li>•Possibilities for technological response</li> </ul>	Increase in ultraviolet radiation striking the Earth's surface because of ozone layer destruction	(International) Vienna Conventions Montreal Protocol (Domestic) ozone layer protection laws	•Total elimination of freon by 1996	

[continued]

[Continuation of Table]

	Cause/characteristics	Effects	Framework for countermeasures	Global technological response	
				Environmental technology (ex)	Effects of environmental technology
Global planning	•Destruction of tropical rain forests through deforestation	11.3 M ha of tropical rain forest destroyed annually	(International) UNCED "Declaration of Forest Principles"	•Fertilizer technology for tropical rain forests and deserts •Soil erosion prevention technology •Water retention technology	Forest preservation, progress in growing plants in deserts (international contribution)
	•Besides drought, human activities like fuel gathering are causes	Desertification of 6 M ha annually	(International) Desertification Prevention Convention (planned for 1994)		
Sea contamination prevention	•Marine accidents, disposal of waste in the oceans, hazardous materials from rivers are causes	North Sea pollution. 90% of cause is waste water	(International) International Seas Convention (planned for 1995)	•Waste water processing technology •Technology for oil spill recovery	•Reduction of contaminated water flowing into the sea from rivers •Response to crude oil contamination
General waste	•Basically a human problem	Garbage is increasing, and the possibility for landfill use for Tokyo is 4.2 years	(Domestic) Recycling laws Waste purification laws	•Biodegradable plastic production technology •Waste recycling technology	Increase recycling fields, improve recycled source functions
Hazardous waste	•Basically a human problem	Bad effects of the leakage of hazardous chemicals and materials on plant and animal life, overseas	(International) Basel Convention (transporting across borders) (Domestic) Basel Law (proposed) [illegible] law	•Technology for alteration of hazardous chemicals •Hazardous materials processing technology	Reduction of the danger of hazardous materials

### III. Outlines of Main Projects in Energy and Environmental Technological Development

There is a necessity for promoting each project in "energy and environmental technological development" as follows

(i) Promotion based on the work priorities indicated earlier for "accelerated projects," "projects for developing revolutionary technology," "joint research on appropriate technology" and "global environmental and industrial technological development."

(ii) In terms of other projects currently in progress, ordering according to comprehensive use of joint technology for all projects as "prioritized projects," and promotion according to the "prioritized progress of energy and environmental technological development" indicated earlier.

#### 1. New Sunshine Project

##### 1) Accelerated Projects

##### (1) Photovoltaic Power Generation (see Chapter II)

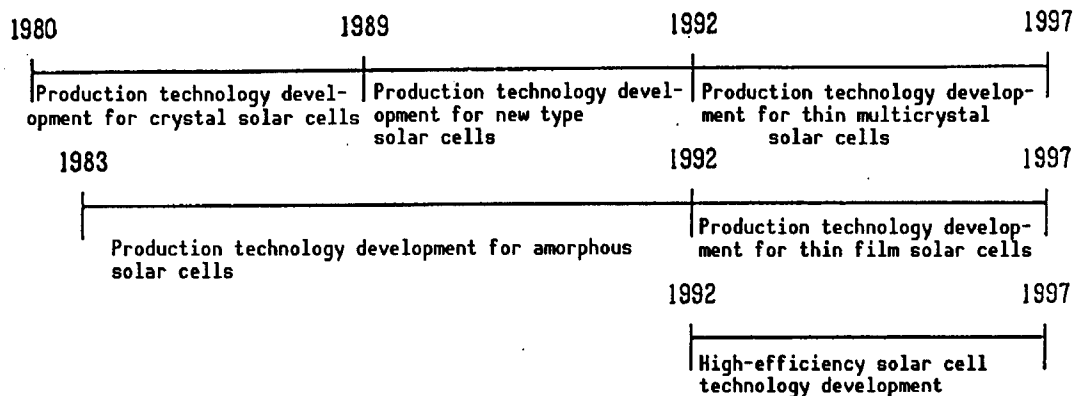
###### • Outline

Establish the necessary technology for early applications of photovoltaic power generation systems as sources of power and for improvements in supply over the long term. Carry out development of utilization systems for photovoltaic power generation for the large-scale downcosting of photovoltaic power generation, technological development for higher performance and establishment of systems utilization technology.

###### • Breakthrough Points

- \* Low cost basic production technology for thin multicrystal solar cells and multicrystal cell module mass production technology
- \* Applications research for high quality, larger area and high reliability thin film solar cells
- \* Elemental research such as materials research for solar cells with high efficiency solar cell compounds
- \* R&D for system evaluation technology and solar cell performance and reliability evaluation technology for all kinds of cells
- \* R&D for performance and reliability evaluation of invertors, etc.
- \* R&D for materials structure and construction of system and peripheral equipment stands

• Development Schedule



• Cost                      FY1974-1992

Photovoltaic power generation system (NEDO)      approximately      ¥85.4 billion  
Same as above, analysis and evaluation funds

(ETL and four others)                      approximately      ¥ 2.3 billion

(2) Fuel Cell Power Generation Technology (see Chapter II)

•Outline

Promotion of fuel cell power generation systems for which use of fuels with high power generation rates such as natural gas, methanol and gasified coal is possible and which have wide applicability from small-scale dispersed systems to large-scale systems and have a low impact on the surrounding environment, in order to promote energy conservation and alternatives to oil in the field of power generation.

• Breakthrough Points

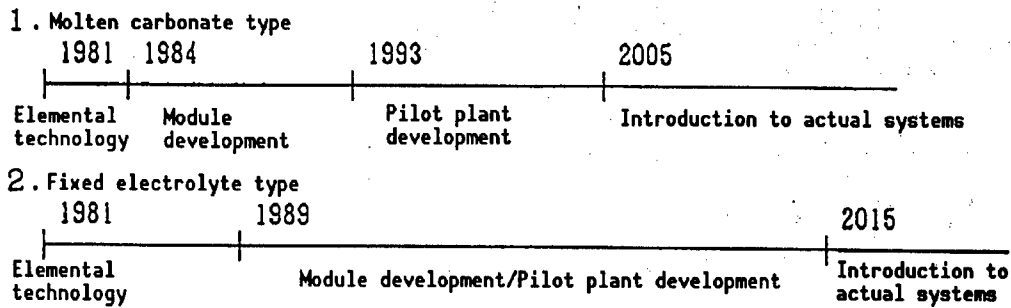
1. Molten carbonate type

- (i) in terms of the fuel cell itself (a) technology for increasing cell surface area and greater lamination, (b) materials development for greater capacity and longer life, (c) materials development and system development for lowering costs
- (ii) integration and size reduction for reformer and heat exchanger, system development for lowering costs
- (iii) development of high performance, long life reforming catalyst
- (iv) establishment of optimal total system at the application stage
- (v) development of technology for handling coal gas

2. Fixed electrolyte type

- (i) in terms of the fuel cell itself (a) materials development for greater volume and higher capacity, (b) establishment of basic structure for several kW module
- (ii) examination of optimal total systems according to use

• Development Schedule



• Cost

1. Molten carbonate type

FY 1984-1997 approximately ¥44 billion (FY92 ¥18 billion)

2. Fixed electrolyte type

FY 1989-1997 approximately ¥10 billion (FY92 ¥1.7 billion)

2) Revolutionary Technology Development Projects

(1) Wide Energy Network System (Eco-Energy City)

•Outline

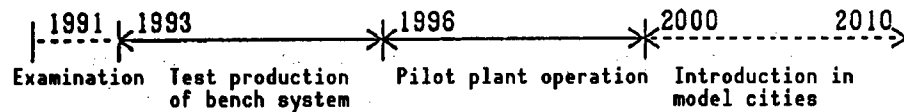
Of the total amount of energy supplied, the percentage used as thermal energy is about 5%. On the other hand, of the total primary energy supply about 6% is not used effectively and is lost, mainly being radiated out in the form of thermal energy. Focussing on thermal energy, which carries the most weight in this form of energy, the goal is for contributing to the relief of energy and environmental constraints through thoroughly effective utilization.

•Breakthrough Points

In order to promote thoroughly efficient utilization of thermal energy, it is indispensable to have

- (i) highly efficient, multi-level, multiaspect recovery of industrial waste and unused heat in which there are large losses of comparatively high temperature heat,
- (ii) low loss, long distance (30 km) transportation of recovered heat to areas with requirements for consumer fields, which utilize heat in relatively low temperature forms,
- (iii) along with multifunction supply corresponding to the forms of the needs in the user areas,
- (iv) the realization of multistage, combined cycle utilization of thermal energy.

- Development Schedule



Up to 2000, development of elemental technology, production of pilot plant, carrying out of operational research and establishment of technology.

- Cost

FY1993-2000: ¥50 billion

## Breakthroughs for the Eco-Energy City System

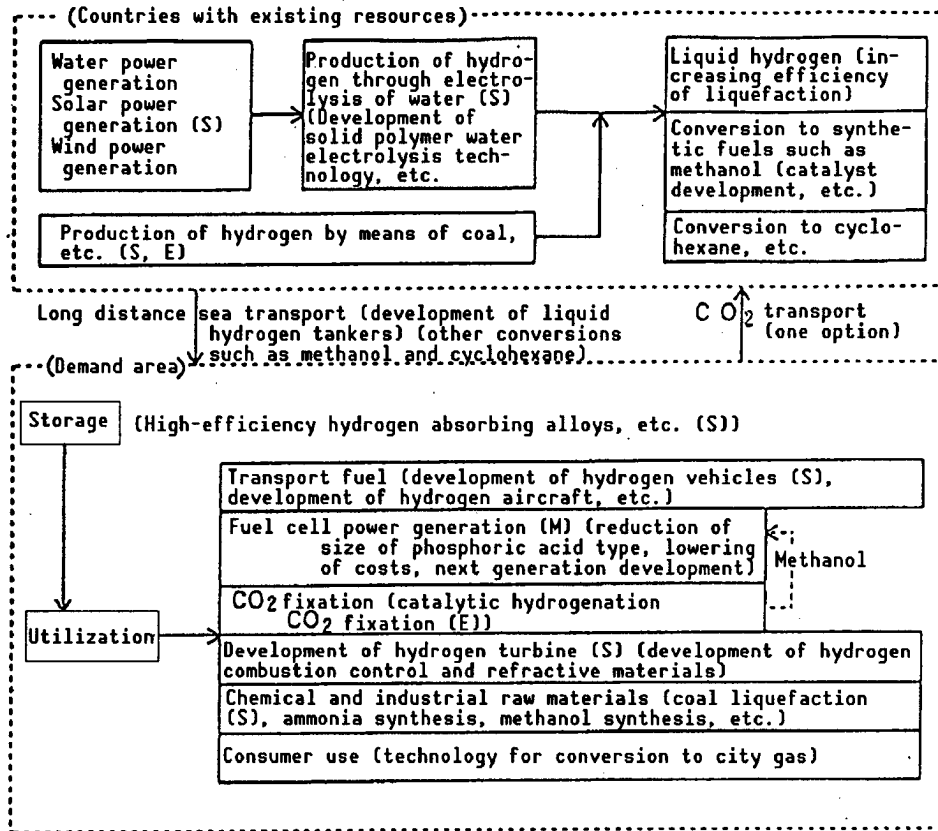
In order to realize thoroughly efficient utilization of wide ranging thermal energy, there is a necessity for carrying out revolutionary technological development for the following topics.

- (i) heat recovery technology (industrial areas, power plants): heat recovery according to temperature range of exhaust heat
  - heat recovery and utilization technology for the limits of usable heat for apparent and latent heat that is thoroughly utilized until the exhaust heat is in the neighborhood of air temperature  
[conventionally: recovery of apparent heat of the 15°C from 100°C to 85°C  
→future: thermal recovery for 50°C from 100°C→50°C]
- (ii) heat transportation technology (industrial areas→housing and commercial areas): high efficiency long distance heat transportation
  - chemical reaction transport and storage technology (thermal transport and storage making use of methanol decomposition reactions that can transport heat about 30 km)  
Through the heat absorbing reaction  $\text{CH}_3\text{CO} + 2\text{H}_2$ , about 150°C of low quality thermal energy is transformed into chemical energy.  
At the point of use, heat is supplied through the heat releasing reaction  $\text{CO} + 2\text{H}_2 \rightarrow \text{CH}_3\text{OH}$  or combustion  
[conventionally: limited by thermal loss and carrier power to several km for latent and apparent heat  
→future: ability to ignore thermal loss over about 30 km]
- (iii) heat supply technology (housing and commercial areas): multifunction heat supply corresponding to the form of use
  - multifunction heat transport and supply technology (hydrogen utilization that can deal with various temperature levels for things like air conditioning, heating, hot water supply)  
[conventionally: one temperature, one machine  
→future: ability to supply any temperature from the thermal transport line]
- (iv) heat utilization technology (housing and commercial areas): cascade combined cycle utilization
  - revolutionary heat utilization technology (low carrier power system)  
[conventional: constrained by carrier power  
→future: carrier power unnecessary]
- (v) energy systemization technology (wide range system): total system optimization
  - establishment of design methods and optimization plan for optimization of cascade utilization system with usage in the order of highest temperatures  
design of system with total introduced energy optimization  
[conventional: single heat source, single user optimization  
→future: multiple heat source, multiple user optimization]

## (2) World Energy Net (WE-NET)

### • Outline

Promoting the goal of constructing a network in which clean renewable energy, such as water power and solar power, which exist in large unused quantities in developing countries, is converted to a transportable form such as hydrogen and transported to user areas, and through international cooperation, development of central elemental technology and system design.

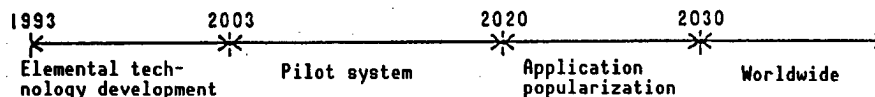


S: Using Sunshine Project results; M: Using Moonlight Project results; E: Using global environmental and industrial technology

### • Breakthrough points

Construction and optimization of total systems for hydrogen production and utilization, high-efficiency hydrogen production technology (fixed polymer hydrogen electrolysis (efficiency: 90% or greater)), long-distance sea transportation technology (liquid hydrogen tankers, etc.), utilization technology (development of high-temperature combustion turbine for power generation (inlet temperature 1,700°C or greater), etc.))

### • Development schedule



Proposed as an initiative by Japan in the international arena of the IEA.

## Technological Breakthroughs for the Realization of WE-NET

### 1. Innovations in Elemental Technology

#### (1) Innovations in hydrogen production technology

##### (i) Increased efficiency in water electrolysis

current 60~70% —————> 90%

↑

- solid polymer water electrolysis technology

##### (ii) Increasing size of electrolysis chamber

current 0.01m<sup>3</sup> —————> 1m<sup>3</sup>  
single cell                   ↑                   300 cells

- Raising of current density
- Development of electrolysis chamber materials
- Technological development for film and pole junction production
- Development of laminating technology

#### (2) Innovations in large volume hydrogen transport technology

- Establishment of long-distance sea transport technology

currently none —————> selection of optima hydrogen and medium conversion system (establishment of conversion technology not established for various systems)

↑

- Liquid hydrogen tanker (in the case of liquid hydrogen: design technology for thermal stress relief tank, utilization technology for vaporized hydrogen)
- Reduction of the basic unit of liquefaction power (in the case of liquid hydrogen)
- Catalyst development for high efficiency hydrogenation and dehydrogenation (for other energy media)

#### (3) Innovations in dispersed storage and transport technology

- Presently, high pressure canister liquid hydrogen storage

—————> development of high hydrogen density (3 times that of hydrogen canister (200 atm)) hydrogen occlusion alloy

↑

- Development of new hydrogen occlusion alloy
- Development of hydrogen occlusion alloy tank for hydrogen vehicles, etc.

(4) Innovations in hydrogen power generation technology

- Establishment of hydrogen turbine technology

currently none —————> inlet temperature of 1,700°C or greater,  
50-60% efficiency

↑

- Development of high reliability refractory materials
- Development of hydrogen combustion control technology

(5) Innovations in CO<sub>2</sub> fixation technology

- Currently none —————> establishment of catalytic hydrogenation  
CO<sub>2</sub> fixation technology

(6) Other

Innovations in fuel cell technology, coal liquefaction technology, ammonial synthesis, methanol synthesis, technology for making city gas, etc.

2. Construction and optimization of total system for hydrogen production and utilization

- Currently, hydrogen utilization is extremely limited, and even in industrial uses there is internal——> production and consumption
- construction of a global production system
- multiplicative exhibition of the effects of commonality, mutual compensation and bidirectionality in energy and environmental technology

### (3) Economic and Ecological Combustion System Technology

#### • Outline

(i) Diesel and lean-burn gasoline vehicles have low fuel consumption and are expected to become popular from the standpoint of reduction in CO<sub>2</sub> emissions and prevention of global warming.

However, since the relative concentration of oxygen in exhaust gas is higher, there is the bottleneck of a large volume of NO<sub>x</sub> emissions.

(ii) In the long term NO<sub>x</sub> emissions restrictions will get stronger. At present, the strengthening restrictions can be dealt with using existing catalyst technology (changes in shape of the combustion chamber, increases in fuel injection pressure, reduction in combustion temperature). In the long term, eradication is indispensable.

(iii) Because of this, we must develop new catalysts for elimination systems that can effectively eliminate (without losing activity in atmospheres with high oxygen concentrations) the NO<sub>x</sub> from diesel and lean burn gasoline engines and simultaneously solve the three problems of energy efficiency, CO<sub>2</sub> removal and NO<sub>x</sub> removal.

#### • Breakthrough Points

Material and structural analysis of catalysts that do not lose activity in atmospheres with high oxygen concentrations.

Improvements in catalyst heat resistance, anticorrosiveness and life. Systemization of fuel engine and exhaust systems.

#### • Development Schedule

FY1993-1997: Selection of prospective catalysts, improvements in catalyst activity, durability improvements. (first phase)

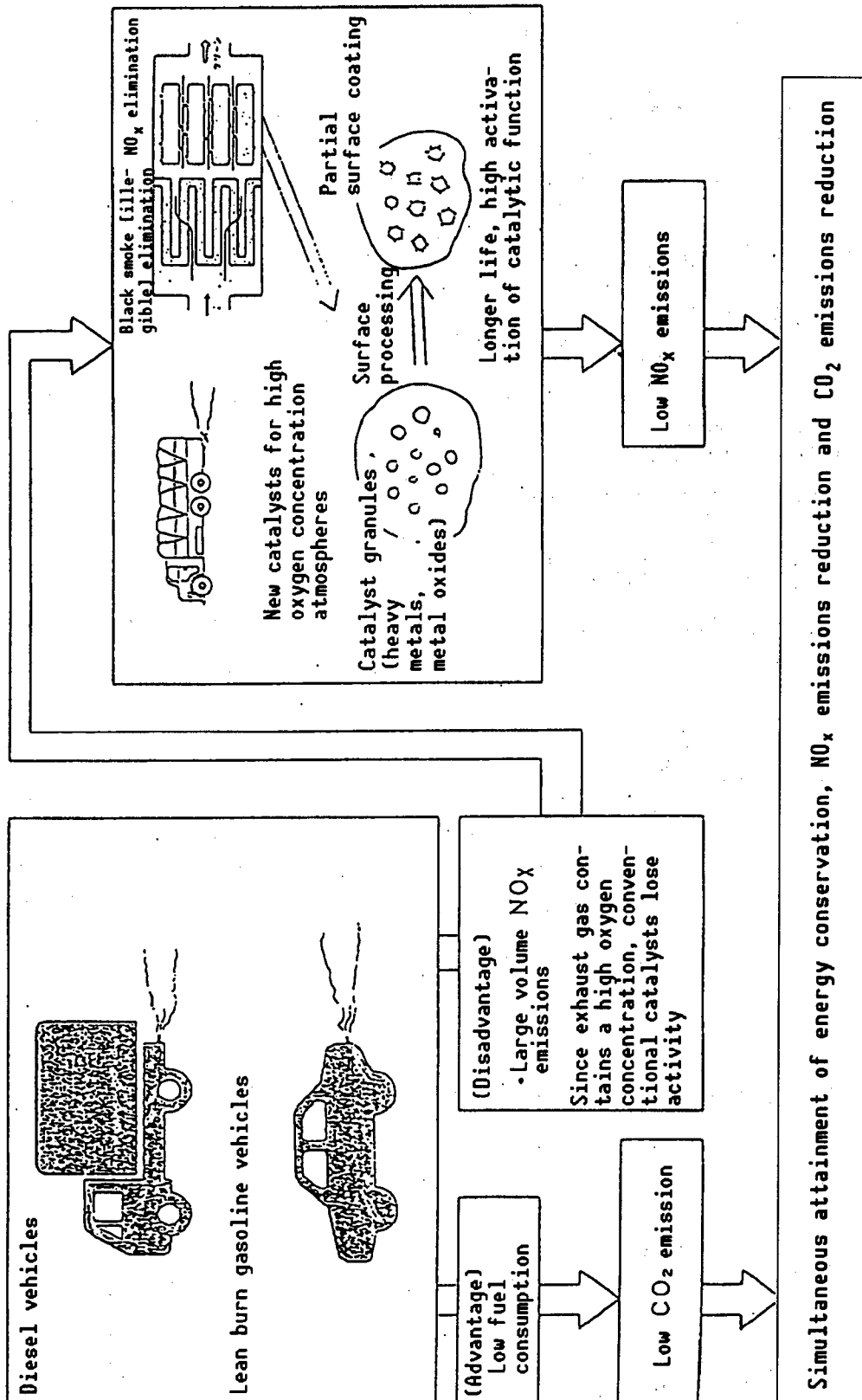
FY1998-2000: Improvements in catalyst and system practicality, tests of total systemization, tests in actual vehicles (second phase)

#### • Costs

FY1993-1997: approximately ¥2 billion (first phase)

FY1998-2000: approximately ¥11 billion (second phase)

Total ¥13 billion



## Concepts for Lean Burn Engine Exhaust Denitrification Catalyst

#### (4) Coal Conversion Complex for Economical and Ecological Energy (Total CE)

- Outline

(i) In order to attain continual growth while assuring energy on a global scale and relieving environmental constraints with the growth of global environmental problems, it is extremely important to develop technology for conversion of coal, which supplies 30% of the world's energy, into clean economical energy.

(ii) However, responding to the above problem is difficult with the current increase in the CO<sub>2</sub> problem and the stability of oil prices, if we are limited to the concept of conventional coal liquefaction. There is a necessity for establishing technology based on new epoch-making conceptions (Total CE: Coal Conversion Complex for Economical and Ecological Energy) that differs from the conventional.

(iii) Through the complex combining of coal and a hydrogen system that uses renewable energy (water power, geothermal power, solar power), centered on the coal liquefaction process, we can pursue the possibility of being able to construct an economical and flexible, efficient and various high-level energy supply and utilization system, along with drastically inhibiting the amount of carbon dioxide generated in the liquefaction and related processes.

- Breakthrough Points

- Construction of an economical and flexible, efficient and various high-level energy supply and utilization system
- Individual technologies (coal liquefaction technology, establishment of renewable energy technology, hydrogen utilization technology)

- Development Schedule

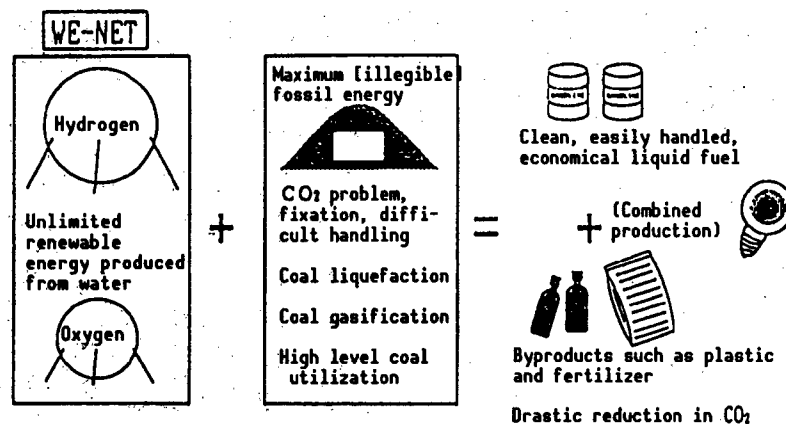
Currently progressing coal liquefaction technology is being anticipated by the whole world as a flag project running at the leading edge of liquefaction technology, and accelerated promotion should be carried out with the above outlook, mustering coal related technology, with Total CE positioned as the central technology

- Costs

FY1974-1997: approximately ¥100 billion

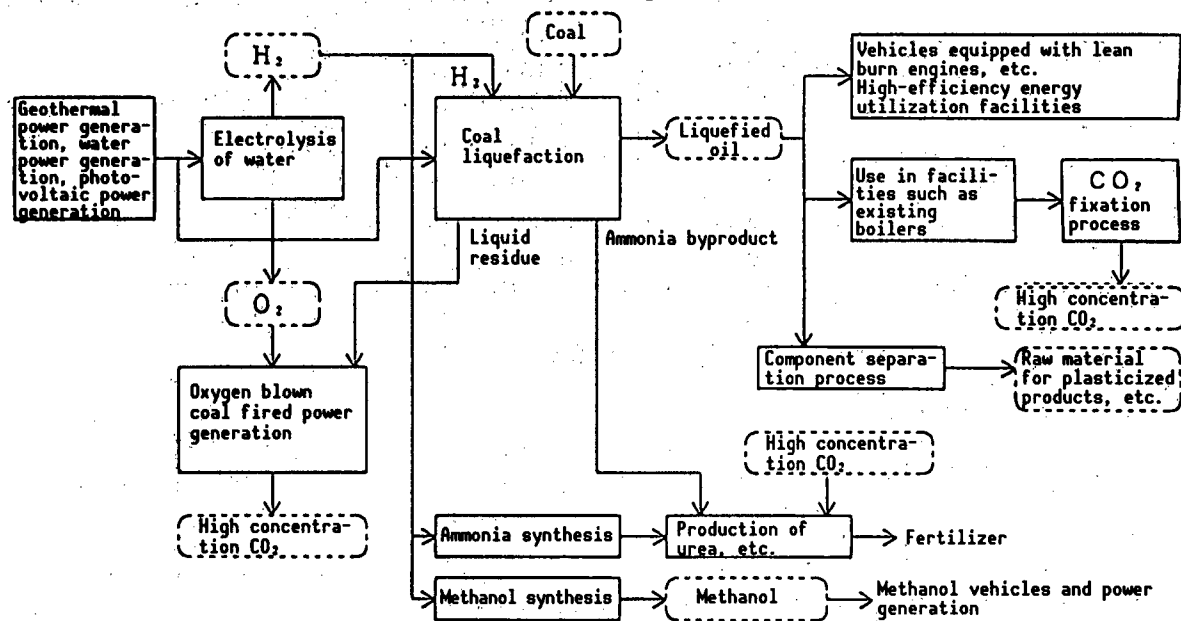
~ FY1992: approximately ¥41.3 billion

(Reference 1) New Conception of Economical and Ecological Coal Conversion Complex



(Reference 2) Concrete Example of Combination of the Coal Liquefaction Process and Renewable Energy

Considering low cost stable supplies of electric power and coal that can be used for liquefaction, there is a large possibility that development will take place with bases for these operations being located overseas (coal producing areas and areas with a wealth of electric power).



(Reference 3) Model Computation of Liquified Coal Oil Costs

- (i) Predicted liquified coal oil costs with current process: \$35/B  
gasoline base

(Of this hydrogen production is about half. \$17-19/B)

↓

Possibility of reduction by half of hydrogen costs through water power from areas with large-scale application (hydrogen production cost

¥16/Nm<sup>3</sup> → Δ\$10/B (approximately))

Note: ¥16/Nm<sup>3</sup> is the cost from P20 hydrogen production cost computation case 1, without the hydrogen liquefaction and transportation costs

- (ii) Predicted cost of liquified coal oil with established complex:  
approximately \$25/B

Furthermore, reductions in power costs are anticipated. In addition, improvements are expected in the liquefaction process itself through future technological developments. Furthermore, there are expectations for reductions in costs through byproducts.

### 3) Joint Research on Appropriate Technology

#### (1) Appropriate Technology for Solar Energy Utilization Systems

##### • Outline

(i) The solar energy utilization system technology developed by the Sunshine Project has almost become practical as fixed temperature storage and freezer technology. In terms of actual applications, it is necessary to match the solar conditions, temperature, humidity and heat requirement patterns of the location of the facility.

(ii) In addition, creation of maintenance-free systems based on the level of technicians who will handle this system technology is indispensable.

(iii) Furthermore, there is a necessity for cost reductions through a shortening of the processes for facilities.

(iv) Joint research on appropriate technological development concerning the above topics will be conducted among the various ASEAN countries for which there are great needs for joint research on the utilization of solar energy in fixed temperature storage and drying facilities for local preservation processing for agricultural products and seafood meant for export, based on local natural environments and societal conditions, and establishment of appropriate technology will be promoted. In this way support will be given to improvement of the ability of the appropriate countries to deal with energy and environmental problems themselves.

##### • Breakthrough Points

- |                |                                                                                                        |
|----------------|--------------------------------------------------------------------------------------------------------|
| Tropical rain: | • Anticorrosiveness                                                                                    |
| forest areas : | • Development of optimal heat cycle design process<br>(optimal freezing cycle, optimal heat collector) |
|                | • Freedom from maintenance (simple exchange system for pumps, use of solar cell driven pumps)          |
|                | • Reduction in construction costs (heat exchangers, modularization of storage areas, etc.)             |
| Dry areas :    | • Resistance to abrasion from sand                                                                     |
|                | • Development of dust resistant optimal heat exchanger (anticlogging measures, etc.)                   |
|                | • Development of design methods for resistance to thermal deformation and thermal fatigue              |
|                | • Freedom from maintenance                                                                             |
|                | • Lowering of construction costs                                                                       |

These breakthrough points are not just the transfer of technology from this country to the country concerned, but rather there is a necessity for promoting the establishment of appropriate technology through the carrying out of appropriate technological development locally with the country concerned, based on the natural environment and technological level.

- **Schedule Phase I (fixed temperature storage, freezer, drying facilities)**

FY1993-1994 conceptual design (type for rain forest areas)  
(type for dry areas)

FY1995-1998 construction and operation of pilot plants  
(durability, maintenance, economic tests)

FY1999-2000 evaluation

Phase II 2000 on  
research, pilot plant construction and operation for industrial  
(150-250°C) heat generation system using solar-chemical heat pump  
technology (alternative for small industrial boiler)

\*1 continuous operation possible with liquid that converts thermal  
energy into chemical energy and stores it.

\*2 Sunshine Project to be completed in FY 1994

- **Costs Phase I (fixed temperature storage, freezer, drying facilities)**

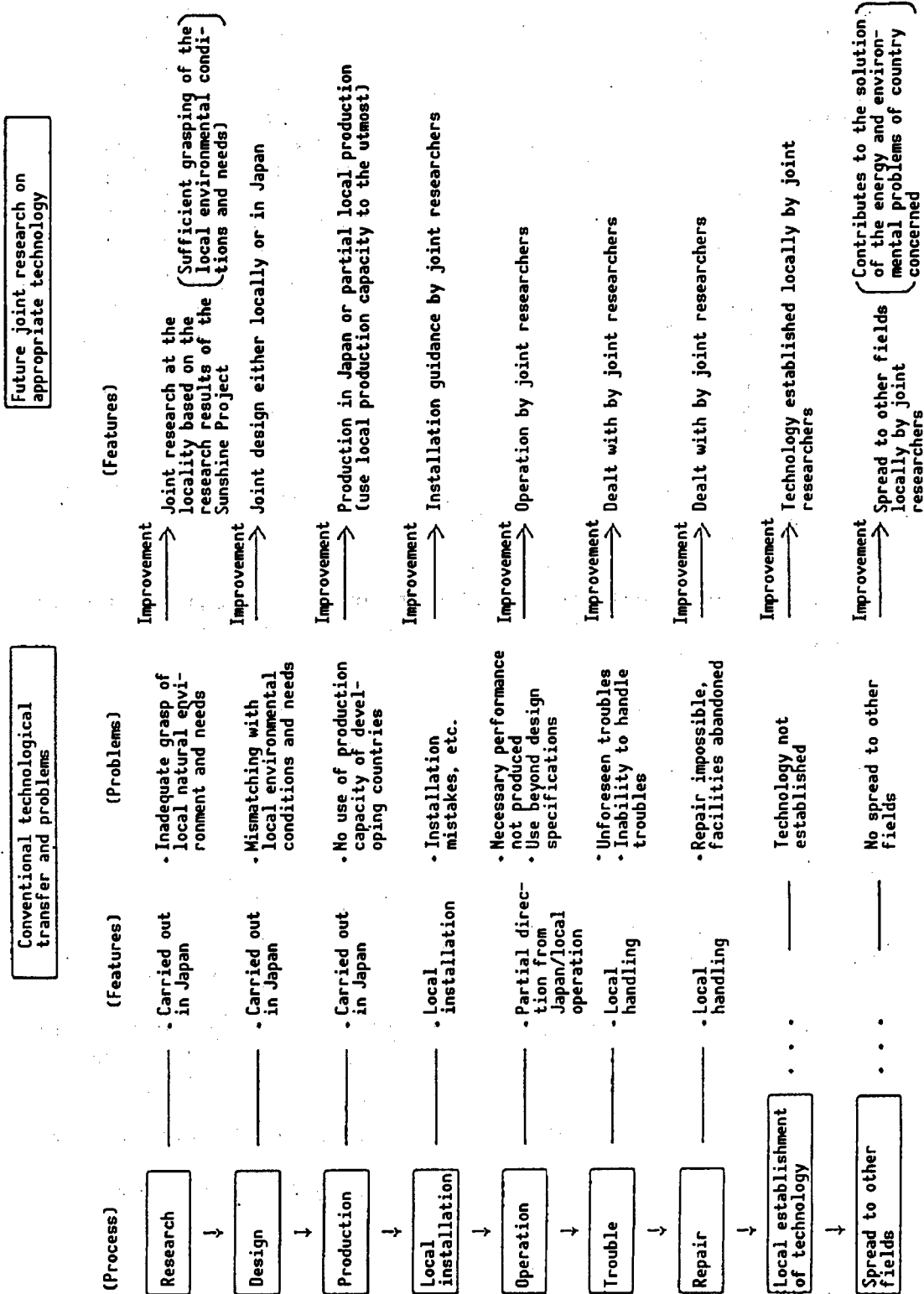
FY1993-1994 ¥1 billion conceptual design

FY1995-1998 ¥9 billion pilot plant construction/operation

FY1999-2000 ¥1 billion evaluation

Phase II FY2000 on approximately ¥15 billion

## Features of Joint Research on Appropriate Technology



Conventional technological transfer and problems

Future joint research on appropriate technology

#### 4) High Priority Projects

##### (1) Solar Heat Utilization Technology

###### • Outline

Development of a solar system that can be used in processes in which various types of high level heat maintenance are necessary in consumer and industrial fields. At present, (i) development of elemental technology, (ii) development of an advanced heat process system, (iii) research on passive solar systems and (iv) research examining solar systems are being carried out.

In addition, joint research on appropriate technology development based on the local natural environment and societal conditions with various ASEAN countries which have strong desires for joint research on solar energy utilization systems developed up to now.

###### • Breakthrough Points

Practical technological development for industrial solar systems

###### (1) Research on elemental technology

In terms of high performance insulation materials, establishment of joint processing technology, carrying out operations with combinations of various elemental technologies in chemical energy conversion technology and establishment of optimal conditions.

###### (2) Development of advanced heat process system

Carry out development of high performance solar freezer and refrigeration systems.

###### (3) Passive solar development

Increase surface area and life of dimmer materials.

###### (4) Research examining solar systems

Carry out examinations of technological development elements for moving forward on the construction of solar cities.

Joint research on appropriate technology

Joint development of solar energy utilization systems technology that fits the natural environments and societal conditions of various ASEAN countries.

###### • Development Schedule

Practical technological development

for industrial solar systems

1992<————>2010

Joint development of

appropriate technology

1993<————>1995<————>1998<————>2000

Conceptual    Pilot plant    Evaluation design

###### • Costs

1974-1992

###### • Practical technological development

for industrial solar systems

¥8.7 billion

###### • Joint development of appropriate technology

0

## **(2) Dispersed Battery Electric Power Storage Technology**

### **• Outline**

1. Demand for electric power in this country is predicted to rise dramatically in the future, and in particular, unbalanced demand for power in the daytime, centered on the summer, is becoming a problem. In order to solve this problem at present, power load equalization technology is centered on the power supply side.

2. Furthermore, in response to requirements for protection of the local environment and the global environment, there is a need for technological development of distributed battery power storage technology that could be used for electric vehicles and in fixed home load conditioners, for power load equalization from the power user side.

3. Considering these conditions and the current state of battery technology, we will develop dispersed battery power storage technology that uses high performance future batteries (lithium secondary batteries), which are maintenance free secondary batteries that assure both environmental protection and safety, with a high energy storage rate and energy density.

### **• Breakthrough Points**

Increasing volume of single cells, increasing performance of single cells and grouped cells (improvements in energy density, life, etc.), improvements in safety and reliability, development of positive poles, negative poles, electrolytes and other structural battery materials for this, establishment of a total system that includes recycling

### **• Development Schedule**

1992	1996	1999	2002
Elemental technology, cell production	Module production	Group cell production, comprehensive testing	Market introduction popularization

### **• Costs**

FY1992-2001: approximately ¥14 billion

### (3) Coal Gasification Technology

#### • Outline

- (i) With the increases in global environmental problems, clean and totally efficient utilization of fossil fuels is an indispensable problem.
- (ii) It is difficult to have both clean and efficient utilization with extensions of conventional technology even in coal gasification, and establishment of new technologies, such as IGCC and HYCOL is necessary.
- (iii) With IGCC the thermal utilization rate is drastically improved by combining gas turbine power generation that uses coal gas as a fuel and a steam turbine that uses the exhaust heat.
- (iv) HYCOL is a multipurpose gasification technology in which pulverized coal is supplied to the gasification chamber along with oxygen and hydrogen and gases for chemical raw materials can be produced with high efficiency from the product gas.
- (v) In addition to the fact that clean energy such as electricity and hydrogen can be produced with high efficiency by IGCC and HYCOL, multiplication of source coals is being promoted for the possibility of handling a wide variety of coal.

#### • Breakthrough Points

For IGCC (i) high temperature dry gas manufacture technology and (i) high temperature gas turbine and materials development are necessary.

For HYCOL, establishment of (i) technology for the continuous extraction of slag from the gasifier and (ii) technology for the prevention of char adhering to the water cooled refractory walls, and achievement of long-term stable continuous operation are necessary.

#### • Development Schedule

	1986	1988	1991	1994
IGCC pilot plant	← Design	→ Construction	→ Operation	→
	1985	1987	1991	1993
HYCOL pilot plant	← Design	→ Construction	→ Operation	→

Design and construction of verification plant expected for both by 2000.

#### • Costs (Pilot Plant Costs)

IGCC to 1992: ¥48 billion, to 1994 Total ¥59 billion  
HYCOL to 1992: ¥11.5 billion

#### (4) Ceramic Gas Turbine Technology

##### • Outline

(i) Develop a 300 kW class ceramic gas turbine using ceramics, which are superior refractive and anticorrosive materials, for improving (20%→4-2%) the thermal efficiency of small gas turbines used for cogeneration or power generation, reducing environmental impact and adding variety to power sources utilizing natural gas, etc.

(ii) In order to do this, carry out (a) research and development for refractory ceramic parts materials that develops important ceramic materials parts technology based on improvements in the durability and reliability of large precise ceramic elemental parts for use in the high temperature section and high precision, high performance processing technology; (b) research and development for elemental technology for converting high temperature parts to ceramics that carries out development for reducing the size of the gas turbine, increases the performance of the various elemental parts and producing a low pollution, high load combustion method; and (c) design and test operation research for developing a ceramic gas turbine with a final goal of a turbine inlet temperature of 1,350°C, which is the world's highest.

##### • Breakthrough Points

(Refractive ceramic parts materials R&D)

- Forming technology for parts with complex shapes
- Firing technology for uniform strength, high precision processing

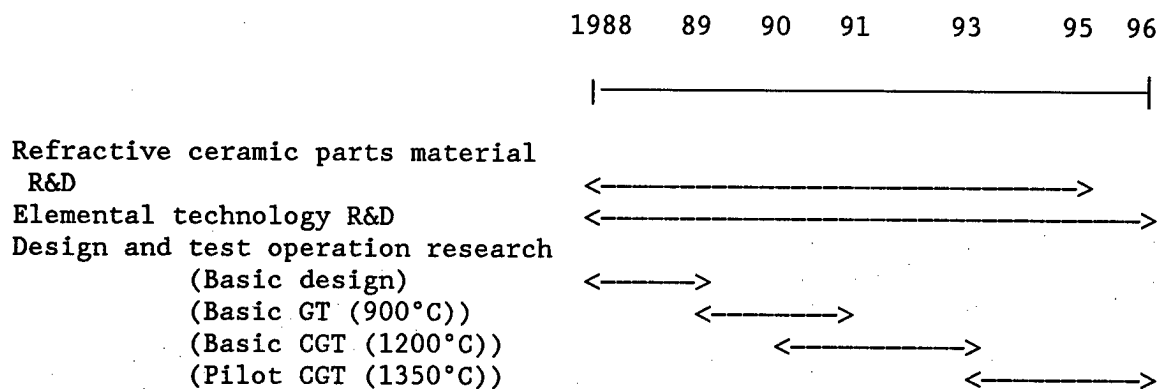
(Elemental technology R&D)

- Low NO<sub>x</sub> firing technology
- Reduction of losses through dirtying of various elements, efficiency improvements

(Design and test operation research)

- Structural safety, operation and control technology for engine system accompanying reduction in size

##### • Development Schedule



##### • Costs

FY1988-1996: approximately ¥16 billion

## **(5) Superconducting Power Generation Applications Technology**

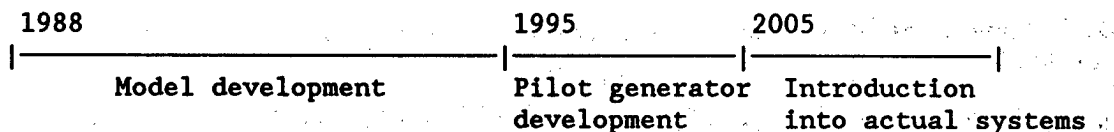
### **• Outline**

Develop a super conductor generator for creation of high stability and high efficiency in the power system and effectively dealing with the difficulties of establishing a power transmission network along with the increased capacity and distancing of power plants and the increases in power losses. In addition, carry out development of metal superconductor line materials and pioneering oxide superconductor line materials that can be used for superconductor power generators. Promote the development of highly reliable freezers for supporting this technology and the development of operations, maintenance and control technology for test methods for super conductor generators.

### **• Breakthrough Points**

- \* Development of super conductor line material with high current density and low alternating current loss that can operate stably in a super low temperature, high speed centrifugal force area,
- \* Development of nonmagnetic material structural rotor with high strength that can withstand high speed centrifugal force and high electromagnetism,
- \* Development of a conductor insulator system that makes insulation of high current possible and development of a cooling system that makes liquid helium flow between the insulator and conductor,
- \* Establishment of freezing system that has high reliability and that makes possible 10,000 hours of continuous operation, \*development of test method for superconductivity characteristics under compression stress that imitates the actual usage environment.

### **• Development Schedule**



### **• Costs**

FY1988-1995: approximately ¥25 billion

## **(6) New Geothermal Power Generation Technology**

### **• Outline**

1. Survey of deep geothermal resources, which exist down deep and are high temperature, but the development of which has been delayed because of the difficulty accompanying extraction, and development of extraction technology.
2. Technical development for power generation in which intermediate to high temperature water is used, heat exchange accomplished using low boiling point media and turbines turned using their steam.
3. Carry out technological development to utilize the heat from high temperature rocks that is not used by current geothermal power generation systems.

### **• Breakthrough Points**

1. Establish a development plan for effective survey methods for deep residing resources and improve the reliability and durability of excavation and extraction technology for geothermal resources.
2. The fundamental technology for the binary cycle power generation system has been established, and construction of a verification plant for verifying economic feasibility is necessary.
3. R&D for water pressure crushing technology for forming an artificial accumulation layer and technology for grasping the character of the crevice formed and R&D for verification of economic feasibility.

### **• Development Schedule**

1. Development of deep geothermal resource survey and extraction technology (1992-2002)
2. Construction of binary cycle test facility (1993-1996)
3. Creation of deep artificial accumulation layer (1993-1996)

### **• Costs**

1. Development of deep geothermal resource survey and extraction technology:  
Total ¥20.4 billion
2. Development of binary cycle power generation system:  
Total ¥7 billion
3. Development of high temperature rock power generation system:  
Total ¥2.9 billion

## (7) Wind Power Energy Technology

### • Outline

With the goal of effectively utilizing wind power energy, which, along with its being a vast energy resource that is clean, renewable and all Japanese built, is not utilized because of its irregularity and low density, we will carry out research and development for creation of large scale ((1) increasing the size of single wind generation systems and (2) collections-wind frames) utilization. In addition, through establishment of wind conditions analysis technology, efficiency of introduction will be raised and costs reduced through mass production.

### • Breakthrough Points

#### (a) Topics concerning wind power generation technology

- (i) materials development: reduction in weight of blades and improvements in hub fatigue
- (ii) control technology: control system for safe stable output
- (iii) new technology for increased size: teetered rotor, variable speed system, flexible structure tower

#### (b) Technological topics for introduction

- (iv) collective sites: distribution, operation and control, and comprehensive optimization as a system
- (v) problem of environmental effects: mainly noise reduction, also effect on natural shapes and view problems
- (vi) establishment of system connection technology for power network, and technology for connection with other systems on outlying islands

#### (c) Future outlook: maritime power generation

### • Development Schedule

1981	—> 1987	100 KW pilot plant
1985	—> 1990	Elemental technology development for large generator
1991	—> 1994	500 KW generator development

### • Costs

Large-scale power generation system (NEDO)	FY 1981-1992
(Same) analysis and evaluation	¥4.3 billion
(Mechanical Engineering Laboratory)	¥400 million

## (8) Sea Energy Technology

### • Outline

- (i) Within sea energy there are types that use the mechanical power of waves, tide currents, and ocean currents, and those that use the thermal energy in oceanic temperature differentials.
- (ii) In the utilization of the mechanical energy in the oceans there is a comparatively high energy density and instability, and control is difficult.
- (iii) Utilization of the thermal energy in the oceans has the problem of low energy density.
- (iv) In terms of wave power generation, there are about 960 mobile power sources in shipping lane marker buoys, etc., in this country alone.
- (v) In terms of oceanic thermal energy conversion, there is a possibility for practical use as a comprehensive operation, if the peripheral operations, such as regeneration of fresh water or use of the highly enriched deep water for cultural purposes are established.
- (vi) There is a necessity for promoting research and development concerning the establishment of the basic elemental technology for solving the problems (ii, iii) concerning sea energy.

### • Breakthrough Points

Establishment of basic elemental technology  
Economic improvements such as lowering construction costs  
Establishment of construction and operation technology that makes possible both environmental protection and preservation

### • Development Schedule

1993	around 2000
Elemental technology development	Pilot system development, practical application and popularization, worldwide popularization (Planning according to progress in elemental technology development)

### • Costs

1993~ Completion of pilot system development: ¥10 billion

## (9) Bioenergy Technology

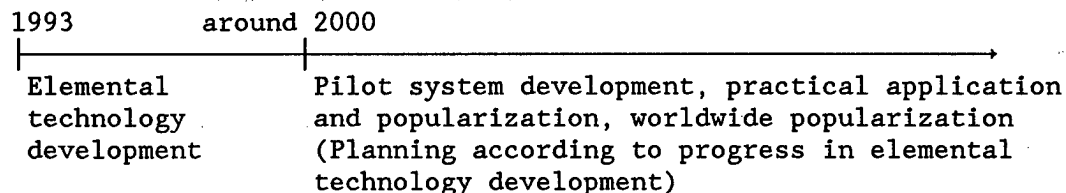
### • Outline

- (i) Since bioenergy is the utilization of the biomass of plants that have been raised fixing CO<sub>2</sub> through solar energy, it is clean renewable energy.
- (ii) There are expectations that contributions can be made to solutions to the problems of desertification and reduction of rain forests through large-scale cultivation.
- (iii) However, consideration must be given to the growth of biomass resources, which are reduced through conversion to energy and to the prevention of the release of greenhouse gasses such as methane with conversion to energy.

### • Breakthrough Points

Establishment of large-scale cultivation and harvesting technology; establishment of high efficiency biomass fuel conversion technology, such as liquefaction, gasification and solidification; increasing biomass resources through the use of biotechnology such as cell fusion and genetic engineering

### • Development Schedule



### • Costs

1993~ Completion of pilot system development: ¥20 billion

## **(10) Magma Power Generation Technology**

### **• Outline**

Current geothermal power generation is nothing more than using steam from water heated by magma, and in the end we can consider a method for directly extracting the Earth's energy that is symbolized by magma.

In order to use the heat of magma directly, research on the properties of magma and research and development for direct use technology for its energy will be carried out.

### **• Breakthrough Points**

After research on the basic form of magma, establishment of search and extraction technology appropriate to this will be established. In particular, the development of materials technology for extracting the heat of magma, with its super high temperature, is necessary.

### **• Schedule**

For the present, along with carrying out basic research concerning the basic form of magma (H5 budget request pending), continuation of R&D for an in-well coaxial heat exchange system as a system for extraction of magma heat.

### **• Costs**

Basic research for coaxial heat exchanger system	¥134 million
Other: undetermined	

## (11) Global Environmental Basic and Foundational Research

### • Outline

In order to deal with global environmental problems such as the prevention of global warming, we aim at establishing the following basic technologies at national research institutes, etc.

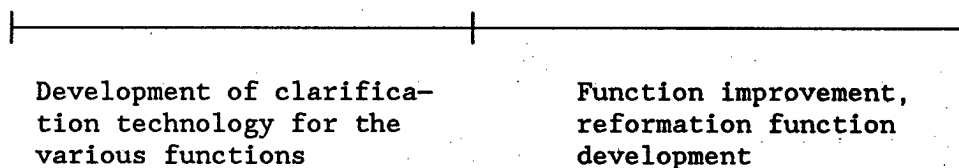
- (1) CO<sub>2</sub> separation and fixation technology
- (2) Technology for material reduction of environmental impact
- (3) Global warming countermeasure evaluation technology

### • Breakthrough Points

- (1) Development of simulations technology for clarification of what happens to CO<sub>2</sub> in high volume fixation
- (2) Clarification and improvement of biodegradation functions, development of processing technology
- (3) Development of simple speed measurement technology

### • Development Schedule

First phase (3-5 years) 1993 second phase (3-5 years)



### • Costs

First phase total: approximately ¥1 billion

Second phase total: approximately ¥2 billion

## 2. Global Environmental and Industrial Projects

### 1) CO<sub>2</sub> Fixation and Efficient Utilization Technology

#### (1) Development of Carbon Dioxide Fixation and Efficient Utilization Technology for Bacterial and Pharmaceutical Usage

##### • Outline

- (i) As a countermeasure for global warming, a research and development project for technology for effective fixation of CO<sub>2</sub> using the photosynthetic function of microorganisms, and along with this the conversion of them into useful materials.
- (ii) Development of breeding, along with searching through the whole natural world for microorganisms with high CO<sub>2</sub> fixation capacities.
- (iii) Development of high efficiency solar light condensing and transmitting devices.
- (iv) Development of a bioreactor that can carry out high density-high volume cultivation using microorganisms and solar energy and development of technology for converting the fixation product into useful material.
- (v) Design, production, testing and verification of a unit plant through the above elemental technology.

##### • Breakthrough Points

- (i) Finding and breeding of microorganisms that have high CO<sub>2</sub> fixation capacities under high CO<sub>2</sub> concentrations and high temperature conditions and high capacity for conversion into useful materials.
- (ii) Technology for efficient spectral concentration and transmission for the visible light in sunlight and for infrared energy.
- (iii) Development of a high efficiency fixation bioreactor that gives the microorganisms being bred the optimal amount of visible light uniformly and conversion technology for conversion to useful materials

##### • Development Schedule

FY1990-1994: development of microorganism search, breeding, solar light concentration and transmission device, development of optimal cultivation and useful material separation process

FY1995-1999: design, production and verification through testing of unit plant.

##### • Costs

FY1990-1994: approximately ¥6 billion (first phase)

FY1995-1999: approximately ¥8 billion (second phase)

## (2) Carbon Dioxide Fixation Using Catalytic Hydrogenation Reactions and Development of Efficient Utilization Technology

### • Outline

The large volume of CO<sub>2</sub> emissions into the atmosphere has become a problem, but we will recover this and synthesize useful materials

The high concentration CO<sub>2</sub> recovered from the fixation source will be recovered continuously in large volume using separate polymer films, and through the addition of hydrogen to the CO<sub>2</sub> recovered, useful chemical materials will be synthesized.

In terms of useful chemical materials, development will progress centered on methanol.

Rather than using fossil fuels for the hydrogen for reactions with CO<sub>2</sub>, clean natural energy can be considered.

### • Breakthrough Points

Development of film materials with the goal of concentrating CO<sub>2</sub> with lower separation energies and higher concentrations.

Development of catalysts with excellent low temperature activity, minimal water effects and interference, low CH<sub>4</sub> conversion rate and high methanol selectivity.

Find structural materials for electrolysis chambers with which an electrolysis efficiency of 85% can be obtained.

Data acquisition for improvement in durability of metallic hydrogenators.

Case studies of the material and energy balance of the process.

### • Development Schedule

FY1990-1994

Design of separation film search and production evaluation; catalyst search, design and performance evaluation; examination of high efficiency, large volume hydrogen generation processes

FY1995-1999

Bench plant testing, verification plant design, construction testing, examination of total system

### • Costs

FY1990-1994: approximately ¥4.3 billion

FY1995-1999: approximately ¥5.5 billion

Total approximately ¥9.8 billion

FY1992 approximately ¥800 million

### **(3) Development of Technology for Carbon Dioxide High Temperature Separation, Recovery and Reuse**

#### **• Outline**

Development of technology and systems for efficient utilization of high temperature CO<sub>2</sub> in which there is separation and recovery of large volumes of CO<sub>2</sub> from fixation sources while it remains at high temperatures, using ceramic films and in addition reactions of methane, etc., with carbon dioxide, which has reactivity at high temperatures, to produce useful chemical materials such as carbon monoxide.

#### **• Breakthrough Points**

The following development will be carried out with the goal of developing high temperature carbon dioxide separation technology using ceramic separation films and utilization technology for high temperature carbon dioxide.

- a) ceramic separation film and system technology for high temperature separation of CO<sub>2</sub>
- b) high temperature CO<sub>2</sub> utilization technology such as high efficiency reduction technology
- c) verification of CO<sub>2</sub> separation, recovery and utilization systems
- d) optimization of CO<sub>2</sub> separation, recovery and utilization systems and survey research concerning adaptability to cities

#### **• Development Schedule**

R&D for CO<sub>2</sub> separation, recovery and utilization technology (1992-2001)

#### **• Costs**

Total: approximately ¥15 billion

## 2) Environmental Impact Reduction Technology

### (1) Development of New Coolant for Compressor Type Heat Pumps

#### • Outline

Freon made from carbon chlorine and fluorine is widely used in air conditioners, sprays, cleaning of electronic parts and foaming agents.

However, specific freon is stable in the atmosphere, rises to the stratosphere and is broken down by ultraviolet rays, destroying the ozone layer that protects living creatures on the Earth's surface.

Because of this, it was determined worldwide to eliminate specific freon by the end of this century, and furthermore, at the 4th meeting of the countries concluding the Montreal Protocol, there will be an attempt to decide on elimination by the end of 1995. Therefore, there is a rush to develop alternative materials.

In particular, development of an alternative for freon 114, which is used as a coolant for removal of waste heat from compressor type heat pumps, is important.

#### • Breakthrough Points

While considering global environmental problems such as ozone layer destruction and global warming and in order to aid in the development and utilization of industrial exhaust heat as an alternative to petroleum energy in the future, a coolant with the following properties which can be used as an alternative to freon 114 as a coolant for compressor type heat pump systems which obtain high quality heat of 100-150°C from the most universal exhaust heat of 30-60°C will be developed.

- boiling point of an appropriate standard for use of 30-60°C exhaust heat
- high stability at temperatures of 100-150°C
- exhibits a thermal efficiency equal to or greater than that of freon 114
- existence of lubricating oil, etc., with good relative solubility (especially at high temperatures)
- hard to ignite
- does not destroy the ozone layer
- low greenhouse effect
- high stability

There is no material among the candidates for alternatives for freon (that is second generation freon, etc.) that satisfies the above properties, and development of a coolant material with a completely new molecular structure will be developed.

- **Development Schedule**

1990-1994

- (1) Design research for new coolant

In order to carry out the search for a new coolant effectively, investigative research into the properties and chemical structure of current coolants and things related to them will be carried out.

In addition, design research for new coolants will be carried out based on this.

- (2) Synthesis of new coolant and measurement and evaluation of properties

Carry out synthesis of materials that appear to have the necessary properties for coolants and measure and evaluate the basic properties

- (3) Evaluation of the safety and environmental effects of new coolants

Measurement and evaluation of the safety of the materials synthesized as coolants and the effects on the environment.

- **Costs**

For R&D: approximately ¥5.6 billion

- (2) **Research and Development for Biodegradable Plastics**

- **Outline**

Among the many problems associated with global environmental problems, the effect of waste plastics on the environment is important worldwide. This project aims at the development of a completely biodegradable plastic that can be broken down by the microorganisms in the environment (in earth) and finally becomes water and carbon dioxide, one which harmonizes the living activities of mankind with the natural environment.

- **Breakthrough Points**

The creation of a new plastic that has both the producibility and costs like those when plastic is produced, the adaptability to processing when products are processed and the physical and chemical properties of products after production that are the same as the properties of general use plastic.

There is a necessity for easy breakdown in the ground and safety in the breakdown process.

- **Development Schedule**

1990-1997: Development of biodegradable plastic through the examination of three production methods, a method for production of plastic within microorganisms (microorganism production), a method for adding thermoplastic properties to natural materials using chemical and physical methods (induced natural materials), a method for production from petroleum raw materials using chemical synthesis (chemical synthesis).

- **Costs**

1990-1992: approximately ¥200 million/year  
1993-1996: approximately ¥250 million/year  
1997: approximately ¥200 million/year  
Total: approximately ¥1.8 billion

### **3) Environmentally Friendly Production Technology**

#### **(1) Research and Development for High-Level Function Chemical Synthesis Bioreactor**

- **Outline**

(i) Since bioreactors that use reaction structures of organisms constructed under normal temperatures and pressures are low resource and low energy and have little impact on the environment, there are great expectations for them for chemical materials production technology. However, low production efficiency is a bottleneck.

(ii) The objects of conventional bioreactors are high additive value, small production articles like pharmaceuticals. In the long run, the ability to handle mass production type materials production is indispensable.

(iii) In order to do this, elemental technology for three types of control, cell propagation control, gene expression control and control of internal cell energy, will be developed, and bioreactor producibility increased.

- **Breakthrough Points**

Analysis and elemental technology for new cell control mechanisms.  
Development of rearranged cells using multiple gene expression systems

- **Development Schedule**

FY1990-1993: analysis of organism control mechanisms and finding of base material cells for both enzymes and genes  
FY1994-1996: creation of elemental technology for organism control and construction of model production system  
FY1997-1999: construction of model bioreactor and along with optimization, evaluation testing

- **Costs**

FY1990-1993: approximately ¥300 million  
FY1994-1996: approximately ¥300 million  
FY1997-1999: approximately ¥300 million

## **(2) Development of Environmentally Friendly Hydrogen Production Technology**

### **• Outline**

(i) Hydrogen is extremely clean energy, and it is also important in the petroleum refining process and in the efficient utilization of CO<sub>2</sub>.

(ii) There is a need for efficient environmentally friendly production of hydrogen that does not consume fossil resources such as petroleum.

(iii) As new hydrogen production technology that does not make use of conventional methods, efficient hydrogen production technology that makes use of the hydrogen production capabilities of microorganisms will be developed.

### **• Breakthrough Points**

(i) finding photosynthetic microorganisms with superior hydrogen production capabilities and improving breeding

(ii) cultivation technology that makes for most effective hydrogen production capabilities in microorganisms

(iii) technology for effective separation and production of the hydrogen produced

(iv) technology for recovery of useful secondary products

(v) technology for development of high efficiency large-scale hydrogen production systems, comprehensive operations technology

### **• Development Schedule**

FY1991-1998 (8 years)

End of FY1995 accumulation of elemental technology, interim evaluation

End of FY1998 comprehensive system verification, final evaluation

### **• Costs**

FY1991-1998 (8 years): approximately ¥5 billion

### **(3) Development of Basic Technology for Environmentally Friendly Regeneration and Utilization of Metal Materials**

#### **• Outline**

(i) Steel is a basic material that is indispensable to human life as a basic material for construction and machines, and in recent years, along with an increase in steel consumption, the accumulated amount of steel in this country has risen to one billion tons, and at the same time, the amount of waste steel which is scrapped after its mission as steel has been completed is increasing.

(ii) On the other hand, from the viewpoint of environmental problems, there is a need to convert the steel production process to one that produces little CO<sub>2</sub>.

(iii) Therefore, research will be done on processes that utilize scrap, which does not require the reduction energy of the processes in the manufacture of the steel, and research that will contribute both to recycling and environmental problem solution (new generation steel manufacturing process) will be carried out.

#### **• Breakthrough Points**

Establishment of new steel manufacturing technology for effectively carrying out separation of copper, tin and lead, which are difficult to separate from iron with current technology.

#### **• Development Schedule**

FY1991-1994: (i) comprehensive basic investigative research, (ii) elemental research on scrap regeneration technology (solid processing technology, molten processing technology)

FY1994-1998: (i) elemental research for new refining technology, (ii) comprehensive system development, (iii) R&D using large-scale test machinery

#### **• Costs**

FY1991-1998: approximately ¥10 billion

## In Conclusion

This interim summary carries out an examination of the possibilities for breakthroughs using technological development for relieving energy and environmental constraints, and it does not go as far as to indicate a concrete action program for delineating the contribution to attaining the goals of the "Global Warming Prevention Project," etc. From the beginning, this action program necessitates wide-ranging examinations not just from the technological point of view, but rather multifaceted examinations starting with aspects of economic policy, energy policy and environmental policy to which examinations of budgetary aspects and systematic aspects are added, based on reports on "The Existence of Future Energy and Environmental Policy" indicated by the Industrial Structure Council, Advisory Committee on Energy and the Joint Meeting of Energy and Environmental Special Subcommittees of the Industrial Technology Council. Therefore, we would expect that this interim summary will undergo scrutiny in this broad context and contribute to the construction of a comprehensive policy. In addition, since this takes as its main subject the possibilities for breakthrough by means of technological development for the dynamically changing problems of energy and the environment, there is also a necessity for appropriate reexamination based on substantial scientific knowledge, new progress in technology, changes in energy conditions and changes in the conditions of progress in international discussions surrounding global environmental problems.

In any event, there is a need to muster all of those involved and, without slacking off, continually make an effort for "meeting the challenge of energy and environmental technology that allows for continual development," which is a current worldwide concern, and constantly and continually lead the dream of better future possibilities; we hope that this interim summary is one help in doing this.

- END -